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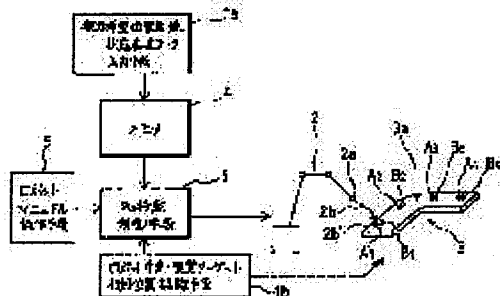
(54) MOVEMENT CONTROL SYSTEM FOR INSTRUCTING POSITION OF ROBOT

(57)Abstract:

PROBLEM TO BE SOLVED: To make instructing operation, which makes good use of a visual sensor and a visual target, efficient.

SOLUTION: A desired instruction position arrival state representation data input means 1a which makes good use of the visual sensor previously inputs data, representing the relative position relation between the visual target B1 and a robot arm tip 2a in a state 2b' wherein the TCP 2b of the robot 2 has finished moving to a desired instruction position A1, etc., to a memory 4. An operator operates a robot manual operation means 5 such as a jog feed button to make a shaft movement control means 6 control respective shafts, thereby starting jog movement. Further, the mode is shifted from the job movement mode to an autonomous movement mode and the TCP 2b is autonomously moved to the desired instruction position A1, etc. Control over the autonomous movement is performed on the basis of the desired instruction position arrival state representation

data and data obtained by a robot arm tip-visual target relative position recognizing means 1b which utilizes the visual sensor. A target means is actualized by a mark coordinate system or light spot projection means.



CLAIMS

[Claim(s)]

[Claim 1] A visual sensor provided with an image processing means which processes a picture acquired through a camera means attached to a hand part of a robot and this robot, and this camera means, In a movement control system of a robot for moving said robot to a position wishing instruction using a control means of a system containing a robot control device, A position attainment state storage step wishing instruction which makes said control means memorize position attainment state representation data wishing instruction which expresses a position attainment state wishing instruction about at least one position wishing instruction, An impaction efficiency stage wishing instruction of moving said robot to said position wishing instruction by movement controls of said robot by said control means, Instruction positional data including a teaching-positions storage step which said control means is made to memorize said impaction efficiency stage wishing instruction, Include an autonomous movement execution phase to which movement in this position wishing instruction is made to carry out autonomously based on said position attainment state representation data wishing instruction, and said position attainment state representation data wishing instruction, It is what is acquired through seeing from said visual sensor expressed using a visual target means which can be recognized with said visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction, In said autonomous movement stage said visual target means, It is what provides a guidance visual target means for showing said robot to said position wishing instruction through being recognized by said visual sensor, By software processing within said control means, movement controls of said robot in said autonomous movement stage are performed, and said software processing, Said method with which a recognition state of said guidance visual target means by said visual sensor includes processing for deriving said robot so that it may be in agreement with a recognition state corresponding to said position attainment state representation data wishing instruction.

[Claim 2] Said visual target means is a mark means including a mark coordinate system which can be recognized with said visual sensor, Position attainment state representation data wishing instruction memorized by said position attainment state storage step wishing instruction, Data showing a position and a posture of said mark coordinate system on a picture is included, and said mark means, A movement control system for position instruction of a robot indicated to claim 1 which is what prepares said mark coordinate system for said position wishing instruction, and a position with fixed relative relation in order to provide said guidance visual target means.

[Claim 3] A movement control system for position instruction of a robot indicated to claim 2 with which it is a mark member which said mark means can fix on a field of a representation work made into an object of teaching work, and said mark coordinate system is drawn on this mark member.

[Claim 4] In [said visual target means is the light spot formed on a floodlighting side of an optical beam light projection means supported by said robot, and] said position attainment state storage step wishing instruction, In order to prepare said position

attainment equivalent state wishing instruction to said visual sensor, A reference floodlighting side for forming said light spot in a position which is in agreement at an instruction target point of said robot is arranged, and it lets it pass to recognize light spot formed on this reference floodlighting side with said visual sensor, It is acquired by said position attainment state representation data wishing instruction so that data showing a position on a picture of said light spot may be included, and said autonomous movement stage, It is what is performed where said optical beam floodlighting direction which removed said reference floodlighting side and was seen from said camera in said position attainment equivalent state wishing instruction is maintained, Movement controls of said robot in said autonomous movement execution phase, It is carried out, using light spot which floodlights said optical beam and is formed on a field where said position wishing instruction exists as said guidance visual target means, and a recognition state of said light spot by said visual sensor said software processing for movement controls of said robot, A movement control system for position instruction of a robot indicated to claim 1 include processing for deriving said robot so that it may be in agreement with a recognition state corresponding to said position attainment state representation data wishing instruction.

[Claim 5]A stage of jogging before an autonomous movement execution phase to said position wishing autonomous instruction is included in a move execution phase to said position wishing instruction, A movement control system for position instruction of a robot indicated in any 1 paragraph of claim 1 - claim 4 to which shift to a move execution phase from said jogging stage to said position wishing autonomous instruction is automatically performed by said control means based on an output of said visual sensor.

[Claim 6]Data showing a position on a picture of said guidance visual target means by which software processing in an autonomous movement execution phase to said position wishing instruction is recognized by said visual sensor at the time concerned, Processing which compares said position attainment state representation data wishing instruction, and processing for carrying out the movement controls of each axis of a robot based on said comparison result, It is what repeats sequentially processing which judges completion / un-completing of a position attainment state wishing instruction until a judgment of position attainment state completion wishing instruction is made, A movement control system for position instruction of a robot with which said teaching-positions storage step is performed after a judgment of this position attainment state completion wishing instruction is made and which was indicated in any 1 paragraph of claim 1 - claim 5.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]Concerning the movement control system for position instruction of a robot in more detail, this invention relates to the movement control system for moving a robot to the position wishing instruction quickly using a visual target and the visual sensor which recognizes this.

[0002]

[Description of the Prior Art]Most generally as a position teaching method of a robot, the method by jogging (robot motion by a manual input) is used. According to this teaching method, an operator operates the jogging button of a teaching control panel, and moves a robot to the position wishing instruction, and the work of teaching the position at that time to a robot is done. When off-line instruction is made and coarse position instruction has ended, or when making correction of teaching positions, fine adjustment of the teaching positions by jogging is performed.

[0003]use any -- since the work for which a robot is moved to it locating [to wish] is done by viewing with slight accuracy in relative position and posture relation of a robot hand (or end effector) and the point wishing [instruction], an operator takes skill to it. As for the number of points (a position and a posture) to be taught, since it is usually to attain to a large number, it is not new to spend great time on teaching work, either. The teaching work depending on viewing of an operator tended to produce variation for instruction accuracy, and there was a problem also in respect of reliability.

[0004]

[Problem(s) to be Solved by the Invention]This invention is made in order to conquer such a situation. That is, the purpose of this invention eases the burden which takes for an operator at the time of teaching work, and there is in providing the movement control system for position instruction of the robot which enabled improvement in the efficiency of teaching work, and reliability.

[0005]

[Means for Solving the Problem]This invention was made in view of a problem of the above-mentioned conventional technology, and an aforementioned problem is solved by enabling it to move a robot to a position wishing instruction autonomously using a visual sensor and a suitable visual target means. A position attainment state storage step wishing instruction which a control means of a system which contains a robot and a visual sensor in many stages of a method of this invention for position attainment state representation data wishing instruction expressing a position attainment state wishing instruction of a robot is made to memorize, An impaction efficiency stage wishing instruction of moving a robot to a position wishing instruction by movement controls of a robot by this control means, and a teaching-positions storage step which makes a control means memorize instruction positional data are included.

[0006]And it is the important feature of this invention that an autonomous movement execution phase made to carry out to this impaction efficiency stage wishing instruction autonomously based on position attainment state representation data wishing instruction which had movement in a position wishing instruction memorized is included.

[0007]In order to make it possible, this autonomous movement position attainment state representation data wishing instruction, It is acquired through seeing from a visual sensor expressed using a visual target means which can be recognized with a visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction.

[0008]A visual target means is used in an autonomous movement stage as a guidance visual target means for showing a robot to said position wishing instruction through being recognized by a visual sensor.

[0009]Software processing performed within a control means for autonomous movement is performed so that a recognition state of a guidance visual target means by a visual

sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived. The visual target means can take a gestalt of a mark means including a mark coordinate system which can be recognized with a visual sensor. In that case, data showing a position and a posture of a mark coordinate system on a picture will be contained in position attainment state representation data wishing instruction memorized by a position attainment state storage step wishing instruction. On the other hand, this mark means is used in order to prepare a mark coordinate system for a position with fixed in order to provide a guidance visual target means for autonomous movement of a robot relative relation as a position wishing instruction. And a robot is derived so that a recognition state of a mark coordinate system by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction by movement controls based on software processing performed within a control means.

[0010]A mark member fixable on a field of a representation work made into an object of teaching work can be used for a mark means. On this mark member, a mark coordinate system is drawn by a dot pattern etc.

[0011]There is light spot formed on a floodlighting side of an optical beam light projection means supported by robot as a gestalt of another available visual target means. When using such light spot as a visual target means, in order to prepare a position attainment equivalent state wishing instruction to a visual sensor in a position attainment state storage step wishing instruction, it is an instruction target point (a point which it is going to coincide with a position wishing instruction) of a robot about light spot. Usually, it is tool point;TCP. A reference floodlighting side for forming in a position in agreement is arranged.

[0012]The optical beam floodlighting direction is adjusted and light spot is formed in an instruction target point position on this reference floodlighting side. This state is equivalent to a teaching-positions attainment equivalent state for a visual sensor. Then, light spot is recognized by a visual sensor, and position attainment state representation data wishing instruction is acquired so that data showing a position on a picture of light spot may be included.

[0013]An autonomous movement stage is performed where the optical beam floodlighting direction which removed a reference floodlighting side and was seen from a camera in a position attainment equivalent state wishing instruction is maintained. That is, movement controls of a robot in an autonomous movement execution phase are performed, using light spot which floodlights an optical beam and is formed on a field where a position wishing instruction exists as a guidance visual target means. Software processing for movement controls of a robot is performed so that a recognition state of light spot by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived.

[0014]In advance of autonomous movement to a position wishing instruction, it may be made to jog in order to perform preliminary approach to a position wishing instruction. As for shift to an autonomous movement stage from a jogging stage, in that case, it is preferred to be automatically carried out by the processing within a control means based on an output of a visual sensor.

[0015]Software processing in an autonomous movement execution phase to a position

wishing instruction, Processing which compares with position attainment state representation data wishing instruction data showing a position on a picture of a guidance visual target means recognized by a visual sensor at the time concerned, Suppose that processing for carrying out the movement controls of each axis of a robot based on a comparison result and processing which judges completion / un-completing of a position attainment state wishing instruction are repeated sequentially until a judgment of position attainment state completion wishing instruction is made.

[0016]Data of a position on a picture of a visual target means observed in this invention when a position wishing instruction is reached is inputted beforehand, and at the time of autonomous movement to a position wishing instruction. A visual target means is used like a navigation index of robot movement by observing with a visual sensor, and a robot is made to turn and derive to a position wishing instruction.

[0017]By this feature, a position attainment state wishing instruction is attained efficiently, without applying a burden to an operator. The highly convenient nature of a robot at the time of position teaching work can also be further raised by performing shift to autonomous movement from jogging with the automatic change in a system. Therefore, even when a large number [the number of positions wishing instruction], there are few burdens of teaching work and they end.

[0018]

[Embodiment of the Invention]Drawing 1 is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention. The numerals 1a express the position attainment state representation data input means wishing instruction which inputs the data expressing the position attainment state wishing instruction. This position attainment state representation data input means 1a wishing instruction, Visual target B1 Data expressing the relative physical relationship of the visual target B1 in the state where movement in the position wishing instruction of the robot [/ else] 2 was completed, and the robot hand 2a. (it is hereafter called "the position attainment state representation data wishing instruction".) -- it has the function to input into the memory 4 beforehand.

[0019]The position wishing instruction is illustrated by the four numerals A1 on the field 3a of the representation work 3 - A4. B1 drawn A1 - near each [of A4] - B4 are given by the position A1 wishing instruction - A4 representing the position which A1 - A4 express which are visual target means and each correspond, and a fixed relation. The example of a visual target means is mentioned later. In the usual gestalt, each visual target position B1 - B4 and each position A1 wishing instruction - A4 are given so that coincidence may not be carried out, although it is close, but they can also coincide both depending on the case.

[0020]The numerals 2a and 2b express the end point position and instruction target point (usually tool point; TCP) of the robot respectively. In the following explanation, the end point position 2a of a robot shall be represented with the starting point of the coordinate system set up on the flange at the tip of a final arm.

[0021]An operator operates the robot manual operation means (robot motion instruction manual input means; teaching control panel etc.) 5, such as a jogging button, makes the shaft movement control means 6 control each axis of the robot 2, and makes movement in the position wishing instruction start in the time of actual work. The movement controls for autonomous movement in the position wishing instruction from the time of this move

start or a certain point in time after a move start are performed. The position attainment state representation data wishing instruction into which the movement controls for this autonomous movement were inputted by the position attainment state representation data input means 1a wishing instruction, It is carried out based on the relative-position-recognition data showing the relative physical relationship between the robot hand and visual target means (camera fixed to this) at each time.

[0022]The latter data is given once [at least] in the process of movement controls by the relative-position-recognition means 1b between robot hand visual targets. in the position attainment state wishing instruction -- naturally -- TCP2b -- the position wishing instruction -- one is in agreement with A1 (or A2 - A4 one) (it illustrates by numerals 2b').

[0023]The position attainment state representation data input means 1a wishing instruction and the relative-position-recognition means 1b are materialized in the form where a visual sensor is used so that it may mention later. The visual target means B1 - B4 are materialized in the form of the light spot formed of the mark coordinate system or laser beam which can be recognized with a visual sensor. In the following explanation, the gestalt which materializes a visual target means in the form of a mark coordinate system is called "the method 1", and the gestalt materialized in the form of the light spot formed of a laser beam is called "the method 2."

[0024]drawing 2 showed the outline of the hardware constitutions of the system used by this embodiment with the important section block diagram centering on a robot control device -- it is. The robot control device to which the whole was directed with the numerals 30 was equipped with the processor board 31, and this processor board 31 is provided with the central processing unit (henceforth CPU) 31a, ROM31b, and RAM31c which consist of microprocessors.

[0025]CPU31a controls the whole robot control device according to the system program stored in ROM31b. A program, a related preset value, etc. which defined the processing by the side of a robot required to perform autonomous movement to the position wishing instruction else [, such as a created operation program and various preset values,] according to the method 1 or the method 2 are stored in RAM31c. A part of RAM31c is used for temporary data storage for the computation etc. which CPU31a performs. The hard disk drive etc. which were suitably prepared as an external device are used for preservation of program data or a preset value.

[0026]The processor board 31 is combined with the bus 37, and instructions and transfer of data are performed among other portions in the robot control device 30 via this bus combination. First, the digital-servo control circuit 32 is connected to the processor board 31, and the servo motors 51-56 are driven via the servo amplifier 33 in response to the instructions from CPU31a. The servo motors 51-56 which operate each axis are built in the mechanism part of each axis of the robot 2.

[0027]The serial port 34 having a communication interface is connected to the teaching control panel 40, the image processing device 20, and the laser generator 60 with a liquid crystal display section while being combined with the bus 37. However, the laser generator 60 is used by the method 2, and is unnecessary in the method 1.

[0028]The teaching control panel 40 has the size and weight which are the grades whose carrying is possible with an operator, and the jogging button etc. which are used as a robot manual operation means are provided on the panel. In addition, the input/output

device 35 for digital signals (digital I/O) and the input/output device 36 for analog signals (analog I/O) are combined with the bus 37. When signal transfer with an end effector is required, the control section of an end effector is connected to digital I/O35 or analog I/O36. In the example mentioned later, since the arc welding robot's application is considered, the electric power unit of an arc welding torch is connected to digital I/O35.

[0029]The image processing device 20 is the usual thing which made CPU carry out bus combination of program memory, a frame memory, an image processing processor, data memory, the camera interface, etc. The camera 21 is connected to the image processing device 20 via the camera interface. This camera is used for the photography for acquiring the picture of a visual target means in the mode mentioned later. The program data for image analyses needed by the method 1 or the method 2 is stored in program memory.

[0030]Drawing 3 is a figure showing the outline composition of the panel surface of the teaching control panel 40. The display screen 41 is a liquid crystal display, and the detailed data of a movement command program, etc. change it, and it is displayed. The function key 42 is a key which selects the menu displayed on the lower end part of the display screen 41. The teaching control panel effective switch 43 is a switch which switches whether operation of the teaching control panel 40 is effective or invalid.

[0031]The emergency stop button 44 is a button to which the emergency stop of the operation of the robot 2 is carried out. The cursor key 45 is a key which moves the cursor displayed on the display screen 41. A numerical keypad and other keys are provided in the ten key part 46, and input of a numerical value and a character, deletion, etc. can be performed to it.

[0032]Although a series of jogging buttons 47 (J1-J6) are buttons which specify advancing side by side / hand of cut, and the direction of +-, and input a movement command in the normal mode which jogs a conventional system, According to this embodiment (autonomous movement mode), it is used as an autonomous movement command input means to the position wishing instruction so that it may mention later. The details of an embodiment are explained below about the method 1 and the method 2 on the assumption that the above matter.

[0033][Method 1]

[1] The schematic diagram 4 is a figure explaining operation of the autonomous movement in the embodiment by the method 1. On the field 3a of the representation work directed with the numerals 3 as well as drawing 1, a number (here four pieces) corresponding to the number of the teaching points A1 - A4 to wish of mark members MK1-MK4 are stuck. On each mark member, the same mark coordinate system is drawn by the dot pattern so that it may mention later. Mark member MK1 is stuck by the position and the posture in which it corresponds to the position and posture of the point A1 wishing [instruction] correctly. Similarly, the mark members MK2-MK4 are stuck by the position and the posture in which it corresponds to the point A2 wishing [instruction] - the position and posture of A4 correctly respectively.

[0034]The robot which carried out representation only of the hand part circumference carries the welding torch 2c and the camera 21 in the hand part, and TCP2b is set up at the tip of welding torch 2c. By this embodiment, a robot is left from the move starting position Ps, autonomous movement of the TCP2b set up at the tip of the welding torch 2c is carried out to the point A1 wishing [instruction] - A4 one by one, and the case where position instruction is performed in each position wishing instruction is considered.

Generally the starting position P_s of autonomous movement is arbitrary, if mark MK1 of the beginning is a position included in the view of the camera 21.

[0035]Drawing 5 is a figure explaining the composition of the mark member used by the embodiment by the method 1. Reference of the figure constitutes mark coordinate system σ_M from the five circular dots D0 arranged in the shape of a lattice by the interval a on the mark member MK, D1, D-1, D2, and D-2. Dot space a is positive constant value. Therefore, the center position of each dot is set to D0 (0, 0, 0), D1 (a , 0, 0), D-1 ($-a$, 0, 0), D2 (a , a , 0), and D-2 ($-a$, a , 0). As long as it can express a three-dimensional rectangular coordinate system, a mark coordinate system may consist of other patterns.

[0036]Hole MH is provided in the regular position where the mark member MK is suitable. This hole MH points to the position wishing instruction, and when sticking on the field 3a of the representation work 3, a sticking position is chosen so that that representative point (for example, center) may be in agreement with the position wishing instruction. A pasting posture is chosen with reference to direction of mark coordinate system σ_M . That is, if pasting postures differ, the postures taught later also differ. For example, since the pasting posture of MK1 and MK4 in drawing 4 is different 90 degrees, it becomes what differed also in the posture taught later 90 degrees.

[0037][2] Preparation (the calibration of a camera, and acquisition of the position attainment state representation data wishing instruction)

1. Perform the calibration of the camera with the application of suitable calibration method in advance of working starting. Although various techniques are known by the calibration of the camera, the mark member shown here can also be used. The outline is described on the convenience of explanation, and in the back.

[0038]2. Perform acquisition of the position attainment state representation data wishing instruction. First, the mark member MK is fixed to a suitable position. Of course, one of the mark members stuck on the representation work 3 can also be used as it is. First, by jog operation of the normal mode (conventional system), a robot is moved, tool point 2b is coincided with representative point MA of hole MH of the mark member MK, and it is made to take the posture wishing instruction. It means that the position attainment state wishing instruction was realized about the mark member MK by this.

[0039]3. If the position attainment state wishing instruction is realized about the mark member MK, photography with the camera 21 will be made to perform via the robot control device 30, and the picture for creating the position attainment state representation data wishing instruction will be acquired.

4. Image processing of the acquired picture is carried out within the image processing device 20, and the data showing the relative positional attitude of mark coordinate system σ_M to the camera coordinate system of the camera 21 is created (it mentions later for details).

[0040][3] Start movement in the position wishing autonomous instruction from the approach starting position P_s (it expresses in a flange position) shown in processing drawing 4 at the time of the position autonomous movement wishing instruction in the method 1, and explain the algorithm of the processing for attaining movement in the position P_t (it expresses in a flange position) wishing instruction. In the following explanation, since a vector is expressed, sign $\langle \rangle$ is used.

1. Skeleton drawing 7 of an algorithm describes the skeleton of an algorithm required for movement in the autonomous position wishing instruction. The current position (position

at each [under movement in the position wishing instruction] time) T0 of a flange, and the present relative position (relative position at each [in the moving process to the position wishing instruction] time) M0 of a camera coordinate system and a mark coordinate system, As [describe / the geometric relation with the flange position Tg and relative-position (target relative position) Mg of a camera coordinate system and a mark coordinate system in the position attainment state wishing instruction in the position attainment state wishing instruction / into drawing 4]

[0041] And Mg is equivalent to the position attainment state representation data wishing instruction acquired by the above-mentioned preparatory work. C is taught by a camera calibration. The fundamental equation which specifies the relation between these [T0], M0, Tg, and Mg is as follows.

$T0 \cdot CM0 = Tg \cdot CMg \dots (1)$, therefore the following formula (2) which solved this about Tg turn into a basic equation showing the moving-target position on the rectangular coordinate system of a robot.

$$Tg = T0 \cdot CM0 \cdot Mg^{-1} \cdot C^{-1} \dots (2)$$

If the position instruction which makes this Tg a final moving-target point is given to a servo, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, defining the algorithm of the autonomous movement to the position wishing instruction results in the problem which asks for the right-hand side of (2) types concretely.

[0042] (2) Among the right-hand side of a formula, T0 expresses the present position data of the robot, and is data of the character obtained within a robot control device at any time. The data of C is separately gained by a suitable camera calibration (the example of a calibration is mentioned later). Then, it explains from how to calculate M0 and Mg.

[0043] 2. Each of equations M0 of M0 and Mg and Mg expresses the position and the posture of mark coordinate system sigmaM seen from the camera coordinate system (at the time of the completion of the present and approach).

[0044] Since it is positive constant value, the arrangement interval a of the circular dots D0 which constitute mark coordinate system sigmaM (refer to drawing 5) used by this embodiment, D1, D-1, D2, and D-2 is $a > 0 \dots$ It is (3). M0 and Mg are the homogeneous transformation processions of 4x4 expressing the relation between the position and posture between three-dimensional rectangular coordinate systems, and can be placed like a following formula (4).

[0045]

[Equation 1]

$$M = \begin{bmatrix} RM & IM \\ t_0 & 1 \end{bmatrix} \dots (4)$$

Here, 3x3 processions for which RM expresses rotation, and IM are 3x1 processions (vector) showing a position. It considers asking for the equation which RM and IM fill hereafter as an equation which M0 and Mg fill. First, the following formula (5) and (6) defines a vector <e1> and <e2>.

[0046]

[Equation 2]

$$\langle e1 \rangle = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \dots (5)$$

$$\langle e2 \rangle = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \quad \dots (6)$$

As for the information acquired from a visual sensor about mark coordinate system σ_M , the center of each circular dots D_0, D_1, D_{-1}, D_2 , and D_{-2} aims (sight line direction) to be in sight from the starting point of a camera coordinate system. These directions can be expressed with five unit vectors $\langle d_0 \rangle, \langle d_1 \rangle, \langle d_{-1} \rangle, \langle d_2 \rangle$, and $\langle d_{-2} \rangle$ as shown in drawing 6.

[0047] $\delta_{t_{ij}}$ defined by the following formula (7) is introduced about the inner product of these vectors.

$\delta_{t_{ij}} = \langle d_i \rangle \cdot \langle d_j \rangle$ ($i, j = -2, -1, 0, 1, 2$) ... (7) -- here, since all the length of $\langle d_0 \rangle, \langle d_1 \rangle, \langle d_{-1} \rangle, \langle d_2 \rangle$, and $\langle d_{-2} \rangle$ is 1, the absolute value of $\delta_{t_{ij}}$ does not exceed 1.

$|\delta_{t_{ij}}| \leq 1$ (a necessary and sufficient condition for equal mark formation is $i=j$) ... (8)
Although distance from the camera coordinate system starting point to each dot center is unknown, this is placed with t_i ($i = -2, -1, 0, 1, 2$). Naturally these take a positive value.

[0048]

$t_i > 0$ ($i = -2, -1, 0, 1, 2$) ... If (9) is carried out, following equation (10) - (12) will be obtained.

$$t_0 \langle d_0 \rangle = l_M \dots (10) \quad t_1 \langle d_1 \rangle = l_M + a_{RM} \langle e_1 \rangle \dots (11a)$$

$$t_{-1} \langle d_{-1} \rangle = l_M - a_{RM} \langle e_1 \rangle \dots (11b)$$

$$t_2 \langle d_2 \rangle = t_1 \langle d_1 \rangle + a_{RM} \langle e_2 \rangle \dots (12a)$$

$$t_{-2} \langle d_{-2} \rangle = t_{-1} \langle d_{-1} \rangle + a_{RM} \langle e_2 \rangle \dots (12b)$$

Therefore, if an equation of these is solved about RM and l_M and it goes, calculating t_i , M_0 and M_g can be defined. A concrete solution will be explained by a paragraph of how to calculate l_M and M_g , and C showing a position and a posture of a camera coordinate system is described briefly.

[0049] 3. The equation C of C is a procession expressing a position and a posture of a camera coordinate system seen from a flange, and the data is obtained by calibration of the camera 21. Although various techniques are publicly known about a calibration and they can be used, even if it uses mark coordinate system σ_M , a calibration of the camera 21 can also be performed. Here, only the main point is described briefly.

[0050] In three different points as shown with the numerals CB_1 - CB_3 in drawing 4, photography with the camera 21 is performed respectively, image processing is performed and the data P_i ($i = 1, 2, 3$) about a relative position between the starting points of mark coordinate system σ_M and a camera coordinate system is obtained. If data T_i ($i = 1, 2, 3$) of a robot position at the time of they and each photography is combined, the following 3 sets of equations will be obtained. The point which calculates P_i ($i = 1, 2, 3$) is the same as that of M_0 or M_g .

$$T_1 CP_1 = T_2 CP_2 = T_3 CP_3 \dots (13)$$

Under conditions from which three postures of a robot of CB_1 - CB_3 differ mutually, it is possible to solve this equation about C . This condition is set to (14).

Conditions: T_1 and T_2 differ from each posture ingredient of T_3 mutually. ... Data of C

(14) Called for is memorized by a robot control device or image processing device.
About a solution of an equation, it explains supplementarily depending on how to ask for 5.C.

[0051]4. In M0 and Mg asking, and solving equation (10) - (12) here and there, and calculating RM and IM, consider calculating ti (i=-2, -1, 0, 1, 2) first. Therefore, a following formula (15) is replaced.

[0052]

[Equation 3]

$$\langle rM \rangle = \begin{bmatrix} rMx \\ rMy \\ rMz \end{bmatrix} = RM^{-1} \langle IM \rangle \quad \dots (15)$$

And equation (10) - (11) is transformed like following formula (16) - (18) using this.

$$\langle rM \rangle = t0 RM^{-1} \langle d0 \rangle \dots \langle rM \rangle + a \langle e1 \rangle = t1 RM^{-1} \langle d1 \rangle \dots \langle rM \rangle - a \langle e1 \rangle = t-1 RM^{-1} \langle d-1 \rangle \dots$$

(18) -- here, (17) (16) If RM^{-1} is cautious of it being a procession showing rotation, a following formula (19) will be materialized.

$(RM^{-1} \langle di \rangle) - (RM^{-1} \langle dj \rangle) = \langle di \rangle - \langle dj \rangle$ (i, j=-2, -1, 0, 1, 2) ... If this (19) (19) type, and (5) - (8) type and (16) - (18) type are used, following expression-of-relations (20) - (23) will be obtained.

[0053]

$$\| \langle rM \rangle \|^2 = t0^2 \dots (20) \quad \| \langle rM \rangle \|^2 + 2 arMx + a^2 = t1^2 \dots (21a)$$

$$\| \langle rM \rangle \|^2 - 2 arMx + a^2 = t-1^2 \dots (21b)$$

$$\| \langle rM \rangle \|^2 + arMx = t0 t1 \Delta 0 \text{ and } 1 \dots (22a)$$

$$\| \langle rM \rangle \|^2 - arMx = t0 t-1 \Delta 0 \text{ and } -1 \dots (22b)$$

$$\Delta 0, 1^2 < 1, \Delta 0, \text{ and } -1^2 < 1 \dots (23)$$

If it arranges carefully from these formulas for $\| \langle rM \rangle \|^2 + arMx$, $\Delta 0, 1$ and $\| \langle rM \rangle \|^2 - arMx$, and $\Delta 0$ and -1 to become a same sign from conditions (3), (9), a formula (22a), and (22b) respectively, following formula (24a) - (25b) will be obtained.

[0054]

[Equation 4]

$$\| \langle rM \rangle \|^2 + arMx = a \alpha + \sqrt{rMy^2 + rMz^2} \quad \dots (24a)$$

$$\| \langle rM \rangle \|^2 - arMx = a \alpha - \sqrt{rMy^2 + rMz^2} \quad \dots (24b)$$

$$\text{但し、} \quad \alpha + = \frac{\text{def } \Delta 0, 1}{\sqrt{1 - \Delta 0, 1^2}} \quad \dots (25a)$$

$$\alpha - = \frac{\text{def } \Delta 0, -1}{\sqrt{1 - \Delta 0, -1^2}} \quad \dots (25b)$$

If a formula (24a) and (24b) change further, the following formula (26) and (27) will be obtained.

$$\| \langle rM \rangle \|^2 = (a^2 \beta a^+)^2 / (1 + \beta a^-^2) \dots (26) \quad rMx = (a \beta a^+ + \beta a^-) / (1 + \beta a^-^2) \dots (27) \text{ however } \beta a^+, \text{ and } \beta a^- \text{ shall be defined by a following formula (28a) and (28b).}$$

$$\beta a^+ = (\alpha a^+ + \alpha a^-) / 2 \dots (28a)$$

$$\beta = (\alpha + \alpha^{-1}) / 2 \dots (28b)$$

And if the formula (26) and (27) is substituted for the formula (20), (21a), and (21 b) and the conditions (3) and (9) are used, t_0 , t_1 , and t^{-1} can be found with the following formula (29), (30a), and (30b).

[0055]

[Equation 5]

$$t_0 = a \sqrt{\frac{\beta + \beta^{-2}}{1 + \beta^{-2}}} \dots (29)$$

$$t_1 = a \sqrt{\frac{1 + \alpha + \alpha^{-2}}{1 + \beta^{-2}}} \dots (30a)$$

$$t^{-1} = a \sqrt{\frac{1 + \alpha^{-2}}{1 + \beta^{-2}}} \dots (30b)$$

t_2 , t^{-2} , $\langle IM \rangle$, and RM are further calculated as follows using these.

[0056]

[Equation 6]

$$t_2 = \frac{t_1 - t^{-1} \delta_1, -1}{t_1 \delta_1, 2 - t^{-1} \delta_1, 2} t_1 \dots (30c1)$$

($t_1 \delta_1, 2 - t^{-1} \delta_1, 2 \neq 0$ の場合)

$$t^{-2} = \frac{t^{-1} - t_1 \delta_1, -1}{t^{-1} \delta_1, -2 - t_1 \delta_1, -2} t^{-1} \dots (30c2)$$

($t_1 \delta_1, 2 - t^{-1} \delta_1, 2 = 0$ の場合)

$$\langle IM \rangle = t_0 \langle d_0 \rangle \dots (30d)$$

$$\langle RM \rangle = (\langle f_1 \rangle \langle f_2 \rangle \langle f_3 \rangle) \dots (30e)$$

$$\text{但し、} \langle f_1 \rangle = \frac{1}{2a} (t_1 \langle d_1 \rangle - t^{-1} \langle d^{-1} \rangle) \dots (30f)$$

$$\langle f_2 \rangle = \begin{cases} \frac{1}{a} (t_2 \langle d_2 \rangle - t_1 \langle d_1 \rangle) \\ \quad (t_1 \delta_1, 2 - t^{-1} \delta_1, 2 \neq 0 \text{ の場合}) \\ \frac{1}{a} (t^{-2} \langle d^{-2} \rangle - t^{-1} \langle d^{-1} \rangle) \\ \quad (t_1 \delta_1, 2 - t^{-1} \delta_1, 2 = 0 \text{ の場合}) \end{cases} \dots (30g)$$

$$\langle f_3 \rangle = \langle f_1 \rangle \times \langle f_2 \rangle \dots (30h)$$

5. Solve the above-mentioned equation (13) under the conditions (14) of the how [to ask for C] above-mentioned. Modification of an equation (13) will obtain the following (31) and (32).

$$C^{-1} T_1^{-1} T_3 C = P_1 P_3^{-1} \dots C^{-1} T_2^{-1} T_3 C = P_2 P_3^{-1} \dots (32) \text{ -- replacement which followed}$$

following formula (33) - (37) here is performed. (31)

[0057]

[Equation 7]

$$\begin{bmatrix} R_c & I_c \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} C \quad \dots (33)$$

$$\begin{bmatrix} R_1 & I_1 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} T_1^{-1} T_3 \quad \dots (34)$$

$$\begin{bmatrix} R_2 & I_2 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} P_1 P_3^{-1} \quad \dots (35)$$

$$\begin{bmatrix} R_3 & I_3 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} T_2^{-1} T_3 \quad \dots (36)$$

$$\begin{bmatrix} R_4 & I_4 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} P_2 P_3^{-1} \quad \dots (37)$$

Then, the equation (31) and (32) is decomposed into following equation (38) - (41).

$RC^{-1}R_1 RC = R_2 \dots (38)$ $RC^{-1}R_3 RC = R_4 \dots (39)$ $\langle(I-R_1)IC\rangle = \langle I_1 \rangle - RC \langle I_2 \rangle \dots (40)$ $\langle(I-R_3)IC\rangle = \langle I_3 \rangle - RC \langle I_4 \rangle \dots (41)$

Therefore, it becomes a target to calculate RC and $\langle IC \rangle$. Here, a form of an equation (38) and (39) shows that both similar transformation processions expressing the similarity R1 during a rotation procession - R2, R3 - R4, and those similarity relations are RC. Then, the following formula (42) and (43) is obtained considering a vector showing a hand of cut of Ri (i= 1, 2, 3, 4) as $\langle v_i \rangle$ (i= 1, 2, 3, 4). Here, $\langle v_i \rangle$ (i= 1, 2, 3, 4) can be uniquely defined from conditions (14), a definitional equation (34), and (36).

$\langle v_1 \rangle = RC \langle v_2 \rangle \dots (42)$ $\langle v_3 \rangle = RC \langle v_4 \rangle \dots (43)$

RC can be calculated if a relation of a following formula (44) is used.

$(\langle v_1 \rangle, \langle v_3 \rangle, \text{ and } \langle v_1 \rangle \times \langle v_3 \rangle) = RC (\langle v_2 \rangle, \langle v_4 \rangle, \text{ and } \langle v_2 \rangle \times \langle v_4 \rangle) \dots$ About (44)

equations (40) and (41), a form of a following formula (45) is used at a bundle, and if a least-squares method is applied, $\langle IC \rangle$ will be calculated.

[0058]

[Equation 8]

$$\begin{bmatrix} I & -R_1 \\ I & -R_3 \end{bmatrix} \langle IC \rangle = \begin{bmatrix} \langle I_1 \rangle \\ \langle I_3 \rangle \end{bmatrix} - RC \begin{bmatrix} \langle I_2 \rangle \\ \langle I_4 \rangle \end{bmatrix} \quad \dots (45)$$

6. Explain the outline of the process flow for movement in the preparatory work and the position wishing autonomous instruction in the method 1 on the assumption that the explanation item of beyond outline of process flow of movement controls by method 1 1.

- 5. First, it is as follows if supplemented about a preparatory work.

(1) preceding working starting -- the above 3 -- as it came out and explained, move a robot to the three positions CB1-CB3 one by one.

(2) In each positions CB1-CB3, acquire the picture of mark coordinate system sigmaM (one piece) of mark member MK1 on the representation work 3, and acquire the data which expresses the sight line direction based on [each] dots by image processing in the image processing device 20.

(3) Perform processing according to the algorithm explained by above-mentioned 5. within the image processing device 20, and compute and memorize the data (data of RC and <IC>) of camera coordinate system C.

[0059](4) When a camera calibration is completed, move a robot to the position Pt shown in drawing 4, and make the position attainment state wishing instruction over mark MK1 appear.

[0060](5) Acquire a picture of mark coordinate system sigmaM and acquire data which expresses a sight line direction based on [each] dots by image processing in the image processing device 20.

(6) Perform processing according to an algorithm explained by above-mentioned 1.2.4. within the image processing device 20, and compute and memorize position attainment state representation data wishing instruction (data of Mg).

[0061]Autonomous movement in a position wishing instruction is performed by a processing cycle containing many following steps, as shown in a flow chart of drawing 8.

[K1] <d0>, <d1>, <d-1>, <d2>, and <d-2> are calculated by image processing, and M0 is calculated.

[K2] M0 calculated from <d0> calculated at data and Step K1 of Mg memorized, <d1>, <d-1>, <d2>, and <d-2> is compared, and both coincidence/disagreement are judged. If in agreement, since an attainment state to a position wishing instruction is meant, it progresses to Step K6. If inharmonious, since it means not having reached a position wishing instruction, it returns to Step K1 via Step K3 - K5. Various algorithms can be used for evaluation of the degree of coincidence of Mg and M0. for example, what is necessary is to compute the deciding index delta with a following formula (46), and just to suppose approach un-completing, if it is delta<epsilon (epsilon -- enough -- smallness - - a positive value) and is the completion of approach, and delta>=epsilon

[0062]

[Equation 9]

$$\Delta = \begin{matrix} \text{def} \\ \left\| \begin{matrix} (M_0 - M_g) \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \end{matrix} \right\|^2 + \left\| \begin{matrix} (M_0 - M_g) \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \end{bmatrix} \end{matrix} \right\|^2 \\ + \left\| \begin{matrix} (M_0 - M_g) \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix} \end{matrix} \right\|^2 + \left\| \begin{matrix} (M_0 - M_g) \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \end{matrix} \right\|^2 \cdots \end{matrix} \quad (46)$$

[K3] The four-line procession T0 of four rows showing the position and posture of the hand (starting point of the coordinate system set up on the flange) of a robot is calculated and memorized.

[K4] Using the algorithm which explained [above-mentioned] with the data (data of C and Mg) acquired by the preparatory work, the right-hand side of (2) types is calculated

and it asks for the perpendicular slip target position T_g .

[0063][K5] The movement command for going to the perpendicular slip target position T_g is created, a servo is passed, and a robot is moved. If the non-error of a system is perfect, it should result in the position attainment state wishing instruction in the above step K1 - one cycle of K5, but the position attainment state wishing instruction is actually attained in successive approximations for the error of a visual sensor, the error of calculation, etc.

[0064][K6] A robot is stopped and processing is ended.

[Method 2]

[1] In the embodiment by the outline method 2, the light spot formed of a laser beam is used as a visual target means. First, drawing 9 - drawing 14 are added to a reference figure, and the outline of a preparatory work and teaching work is explained. Drawing 9 is a figure for explaining inner-1--3 of many stages of a preparatory work, and drawing 10 is a figure for explaining the remaining stages PR4-PR6. A figure for drawing 11 to explain inner TH1-TH3 of many stages of teaching work and drawing 12 are the figures for explaining stage TH4 and PR5.

[0065][2] Preparatory work (acquisition of position attainment state representation data wishing instruction, and calibration of a camera)

(PR1) a hand of a robot first represented with the flange position 2a -- the camera 21 -- in addition, the laser head 22 (irradiation head of the laser generator 60 shown in drawing 2) and the reference tool 25 are attached. The laser head 22 is attached via the suitable adjustment mechanism 23, and can adjust now the floodlighting direction of the laser beam 24. The mark 26 which expresses TCP (2b) with a portion shown by the arrow 27 near the tip of the reference tool 25 is formed. However, it needs to be cautious of this mark 26 being for viewing. Where the laser head 22 is attached, generally the laser beam 24 does not enter into the mark 26 on the reference tool 25, as illustrated.

[0066](PR2) Direction of the laser head 22 is adjusted and it is made for the laser beam 24 to enter into the mark 26 on the reference tool 25. Thereby, light spot is formed in a position of the mark 26, i.e., position 2b of TCP. The laser head 22 is henceforth fixed in this state.

[0067](PR3) Photography with the camera 21 is made to perform via the robot control device 30 in this state, and a picture for creating position attainment state representation data wishing instruction is acquired. Image processing of the picture of acquired light spot is carried out within the image processing device 20, and data showing the direction of light spot (it is in TCP position 2b.) seen from a camera coordinate system (starting point O_c) of the camera 21 of a vector $\langle et \rangle$ is created and memorized. This data is behind used as position attainment state representation data wishing instruction.

[0068](PR4) If data of $\langle et \rangle$ is acquired, the reference tool 25 will be removed. Since the laser head 22 is fixed, the laser beam 24 will pass along TCP (2b) in the air as illustrated.

[0069](PR5) Data of a vector $\langle eh \rangle$ is created and memorized as a vector showing the laser beam's 24 seen from the starting point O_c of camera coordinate system existence direction. $\langle eh \rangle$ is a vector by which the following two conditions are fulfilled.

Conditions 1; it is in a flat surface which a vector $\langle et \rangle$ and the laser beam 24 stretch.

It is a vector of a direction near a direction which looked at the laser head 22 from the camera 21 among $\langle eh(s) \rangle$ which fill condition 2; $\langle eh \rangle \parallel \langle et \rangle$. $\langle eh \rangle$ can be calculated by a method shown, for example in drawing 13.

[0070] That is, a robot is moved by jogging above the suitable flat surface (here, the representation work surface 3a is used.), and the spot F of the laser beam 24 is formed. And by approach to the field 3a of a robot from a state which has TCP position 2b above the field 3a as shown in (1), as shown in (2), TCP position 2b makes the state of the field 3a of coming caudad. If it puts in another way, it will be made for a position of the spot F to come to an opposite hand from a state of (1) across the look 21a of the camera 21 and the intersection N of the field 3a which look at a TCP position (2b).

[0071] In this state, photography with the camera 21 is performed and a picture of the spot F is acquired. And image processing is performed within the image processing device 20, and it asks for data showing the direction of the spot F seen from a camera coordinate system of a vector <es>. A vector <eh> is computed with a following formula (47) using this <es>.

[0072]

[Equation 10]

$$\langle eh \rangle = \frac{\langle et \rangle \times \langle es \rangle}{\| \langle et \rangle \times \langle es \rangle \|} \quad \dots (47)$$

(PR6) The calibration of the camera 21 is performed. This is for asking for the relation of the flange coordinate system (2a is the starting point) and camera coordinate system which are set up on a robot hand's flange face. Various things are available as explanation of the method 1 described the technique of the KIKYA rib ration of a camera (the technique by a mark member may be used).

[0073][3] teaching work (TH1) by the method 2 -- move a robot first above the representation work surface 3a where the first position wishing instruction exists by jogging, and form the spot F of the laser beam 24 on the representation work surface 3a. Marking of the position A wishing instruction shall be beforehand carried out by the suitable teaching point mark A which can be recognized with a visual sensor. The flange position 2a in the state where it illustrated shall be set to Ps, and autonomous movement shall be started from the position Ps. Shift to autonomous movement from jogging can be considered as an automatic change which used a visual-sensor output, for example so that it may mention later.

[0074] TCP position 2b is above the field 3a, and the laser beam 24 forms the spot F on the field 3a through this point as illustrated. Generally in this stage TH1, three points are in another position mutually [the teaching point mark A and the spot positions F and TCP (2b)]. The look 21a which looked at the teaching point mark A from the camera 21 does not pass along TCP (2b).

[0075](TH2) A robot is operated by processing of autonomous movement and the look 21a which looked at the teaching point mark A from the camera 21 passes along TCP (2b). As operation of a robot, rotation of a circumference of the starting point Oc of a camera coordinate system is rational.

[0076](TH3) A robot is operated by processing of autonomous movement, and a formation position of the spot F is made to approach the teaching point mark A, keeping conditions by which the look 21a passes along TCP (2b) as much as possible. As operation of a robot, rotation of a circumference of Oc should be suitably combined with advance of the direction of look 21a.

[0077](TH4) If advance of the direction of look 21a becomes superfluous, while the look 21a will keep conditions which pass along TCP (2b) as much as possible, in accordance

with the direction of look 21a, it retreats suitably, and rotation of a circumference of Oc is combined suitably.

[0078](TH5) Hereafter, operation (advance) of TH3 and operation of TH4 (retreat) are repeated, and a formation position of the spot F is completed as the teaching point mark A. Since it is exactly an intersection of the look 21a which this convergent point passes along TCP (2b), and looks at the teaching point mark A, and a laser beam which passes along TCP (2b) therefore, it will come to the teaching point mark A and the position in which three points are the same as for the spot positions F and TCP (2b) after all. This means namely that instruction target point slack TCP (2b) reached a position wishing instruction. A position of flange position 2b at this time is expressed with Pt as well as a case of the method 1.

[0079]Then, if a robot position in this state is memorized to a control means (nonvolatile memory in a robot control device), position instruction of the position A will be completed. What is necessary is just to apply the above-mentioned processes TH1-TH5 about each teaching point mark of the 2nd henceforth, when there are two or more positions wishing instruction (teaching point mark) (see the point A1 - A4 on the representation work 3 in drawing 1, for example although a graphic display is omitted).

[0080][4] Explain an algorithm of processing for attaining movement in the position Pt (similarly it expresses in a flange position) wishing instruction from the autonomous movement starting position Ps (it expresses in a flange position) according to a process explained by the processing above at the time of position autonomous movement wishing instruction in the method 2 [2]. Although sign $\langle \rangle$ expresses a vector as well as a case of the method 1, a definition content of a vector is separate from the method 1. Autonomous movement is performed based on a processing cycle according to an algorithm which described an outline in a flow chart of drawing 15 (L1-L12) and drawing 16 (L13-L19). Hereafter, it divides into each step and explains focusing on an algorithm. The meaning of many signs under explanation is as follows.

[0081]sigma0, sigma1 ; A value of 1 [**] is taken with a flag with which all express advance/retreat of a robot. +1 means advance and -1 means retreat.

l; register value [showing the amount of units of advance/retreat of a robot] $\langle dm \rangle$; -- to have been shown in drawing 14 is asked from image data by a unit vector (length 1) showing a sight line direction which looked at the teaching point mark A from the starting point Oc of a camera coordinate system.

$\langle ds \rangle$; to have been shown in drawing 14 similarly is asked from image data like $\langle dm \rangle$ by a unit vector (length 1) showing a sight line direction which looked at spot position F (incidence position of the laser beam 24) from the starting point Oc of a camera coordinate system.

[0082]T; procession deltar which expresses a position and a posture of a robot on a robot-coordinates system, deltal ; Positive constant near [in a threshold with suitable all] 0.

What expresses the minimum rotation with a rotation procession which describes a relation of the direction of R; $\langle dm \rangle$ and $\langle et \rangle$ among 3x3 processions used as $R \langle et \rangle = \langle dm \rangle$.

sgn; it defines as signum as follows.

$\text{sgn}(x) = +1 \ (x > 0)$

$\text{sgn}(x) = 0 \ (x = 0)$

$\text{sgn}(x) = -1 \ (x < 0)$

[L1] Flag sigma0 is initialized to 1. l is initialized to a suitable initial value (for example, 3 cm).

[L2] A register value showing data of the procession T is updated based on a current position of a robot.

[L3] A photograph is taken using the camera 21 and it tries to search for a vector <dm> using the image processing device 20.

[L4] Since it is possible that the teaching point mark A is not caught with a camera view if a vector <dm> is not searched for, processing is ended (an operator is changed into the state where adjust a robot position by jogging and the teaching point mark A is certainly caught with a camera view). When a vector <dm> is searched for, it progresses to Step L5.

[0083][L5] It asks for an outer product of a vector <et> and a vector <dm>, and <dr>=[>] <et> x <dm>.

[L6] As compared with threshold deltar, if not small, he follows an absolute value of a vector <dr> to Step L7. If small, it will progress to Step L10.

[0084][L7] The rotation procession R which describes a relation of the direction of <dm> and <et> is computed by a declared formula. A declared formula is obtained by solving the following simultaneous equations about R.

$$R\langle et \rangle = \langle dm \rangle \dots (48)$$

$$R\langle dr \rangle = \langle dr \rangle \dots (49)$$

[L8] A register value showing data of the procession T is updated to a thing to a procession of a notation containing the new submatrix R. This procession solves the following equation (50) about Tg, and is set to Tg ->T.

[0085]

[Equation 11]

$$T_g C = T C \begin{bmatrix} R & 0 \\ t_0 & 1 \end{bmatrix} \dots (50)$$

[L9] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L8 expresses is performed, and it returns to Step L2.

[L10] By step L6, if it is judged that the absolute value of a vector <dr> is smaller than threshold deltar, this step L10 will be performed for the first time. It tries to search for the unit vector <ds> which expresses with this step the sight line direction which looked at spot position F from the starting point Oc of the camera coordinate system from image data.

[0086][L11] It is thought that it cannot happen that the spot F is not settled in a camera view when [this] an absolute value of a vector <dr> is about 0 (a look which looks at TCP, and a look which looks at a teaching point mark are real coincidence) unless there are a system abnormality, a design error, etc. Therefore, in almost all cases, a vector <ds> is searched for and it progresses to Step L12. However, processing is ended if <ds> should not be calculated (a cause inquiry etc. are performed separately).

[0087][L12] <ds> and <et> are the real same directions, and it confirms whether to be the inner product 1 (it is cautious of deltar being a very small positive value).

[L13] Flag sigma1 showing advance/retreat of a robot will be set to sigma1 =0, if an inner product of <ds> and <eh> is positive, it is sigma1 =-1 and negative and it will become sigma1 =1 and a real target zero.

[L14] If it is $\text{sigma1} = 0$, it will progress to Step L15. If it is not $\text{sigma1} = 0$, it will progress to Step L16.

[L15] sigma1 is updated to sigma0 and it progresses to Step L18.

[L16] If a product of sigma1 and sigma0 is positive, it will progress to Step L18. If it is negative, it will progress to Step L17.

[0088][L17] A value of 1 is reduced by half while updating sigma0 to sigma1 .

[L18] A register value showing data of the procession T is updated to a thing to a declared procession. This procession solves the following equation (51) about T_g , and is set to $T_g \rightarrow T$.

[0089]

[Equation 12]

$$T_g C = T C \begin{bmatrix} 1 & \sigma 1 l < e t > \\ t_0 & 1 \end{bmatrix} \dots (51)$$

[L19] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L18 expresses is performed, and it returns to Step L2.

In the processing cycle according to the algorithm explained above, if the judgment output of yes is obtained at Step L12 at one of the times, it will be understood as the position attainment state wishing instruction as shown in (TH5) of drawing 12 having been realized, a robot will be stopped, and processing will be ended.

[0090] As mentioned above, since movement in the position wishing instruction of a robot will be autonomously performed so that it may become the position of a position attainment state wishing instruction and the posture which it was inputted beforehand if this invention is followed so that I may be understood from the explanation about the embodiment of the method 1 and the method 2, working efficiency improves.

[0091] the method 1 and the method 2 -- also in which embodiment, it is preferred to automate a change in the mode of autonomous movement in which it tends toward a position wishing instruction autonomously, from the mode of jogging by a manual command input by processing inside a control means (the robot control device 30 and the image processing device 20).

[0092] Drawing 17 shows an operating procedure of a teaching control panel, and outline of processing with a flow chart about a case where a change in the mode of autonomous movement of jogging from the mode is performed inside a system. It is as follows when processing of each step is described briefly. An output of a visual sensor is used for determination of timing of a mode change in this example.

[S1] If it judges whether the jogging button 47 (any one) was pushed and instructions of jogging were made, and are made, will progress to Step S2 and it will not be made, Step S1 is repeated.

[S2] According to movement contents (a direction, an axis, etc.) specified with the jogging button 47, a predetermined axis is controlled and jogging movement of the robot 10 is started. For example, if movement of the direction of J6 axis + is specified, a movement command which advances J6 axis in the direction of + will be created, and a servo will be passed.

[S3] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 will not be progressed and used, it progresses to step S4.

[S4] If existence of reception of a signal which tells that the teaching point mark A (a case of the method 2 and the spot F) entered in a view of the camera 13 was checked, it has received and it will not have progressed and received to Step S5, it returns from the image processing device 20 to Step S3.

[S5] Processing of autonomous movement is started. It is as having divided into the method 1 and the method 2 and having mentioned above about an example of the concrete contents of processing.

[S6] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 is not progressed and used, it progresses to Step S7.

[S7] It judges whether it reached to a position wishing instruction, if it has reached, it will progress to Step S8, and if it has not reached, it will return to Step S6. It is as having also described a judgment method which is not reached [the position attainment wishing instruction /] in explanation of the method 1 and the method 2.

[S8] Operation of each axis of the robot 2 is stopped.

[0093]

[Effect of the Invention]According to this invention, since the data of the position on the picture of the visual target means observed when the position wishing instruction is reached is inputted beforehand, using a visual target means like a navigation index, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, the burden of the operator which the position teaching work of a robot takes is eased substantially. The highly convenient nature of the robot at the time of position teaching work can also be further raised by performing the shift to autonomous movement from jogging with the automatic change in a system especially.

TECHNICAL FIELD

[Field of the Invention]Concerning the movement control system for position instruction of a robot in more detail, this invention relates to the movement control system for moving a robot to the position wishing instruction quickly using a visual target and the visual sensor which recognizes this.

PRIOR ART

[Description of the Prior Art]Most generally as a position teaching method of a robot, the method by jogging (robot motion by a manual input) is used. According to this teaching method, an operator operates the jogging button of a teaching control panel, and moves a robot to the position wishing instruction, and the work of teaching the position at that time to a robot is done. When off-line instruction is made and coarse position instruction has ended, or when making correction of teaching positions, fine adjustment of the teaching positions by jogging is performed.

[0003]use any -- since the work for which a robot is moved to it locating [to wish] is done by viewing with slight accuracy in relative position and posture relation of a robot hand (or end effector) and the point wishing [instruction], an operator takes skill to it. As for the number of points (a position and a posture) to be taught, since it is usually to

attain to a large number, it is not new to spend great time on teaching work, either. The teaching work depending on viewing of an operator tended to produce variation for instruction accuracy, and there was a problem also in respect of reliability.

EFFECT OF THE INVENTION

[Effect of the Invention]In this invention, the data of the position on the picture of the visual target means observed when the position wishing instruction is reached is inputted beforehand.

Therefore, using a visual target means like a navigation index, a robot can be turned to the position wishing instruction and can be moved autonomously.

Therefore, the burden of the operator which the position teaching work of a robot takes is eased substantially. The highly convenient nature of the robot at the time of position teaching work can also be further raised by performing the shift to autonomous movement from jogging with the automatic change in a system especially.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]This invention is made in order to conquer such a situation. That is, the purpose of this invention eases the burden which takes for an operator at the time of teaching work, and there is in providing the movement control system for position instruction of the robot which enabled improvement in the efficiency of teaching work, and reliability.

MEANS

[Means for Solving the Problem]This invention was made in view of a problem of the above-mentioned conventional technology, and an aforementioned problem is solved by enabling it to move a robot to a position wishing instruction autonomously using a visual sensor and a suitable visual target means. A position attainment state storage step wishing instruction which a control means of a system which contains a robot and a visual sensor in many stages of a method of this invention for position attainment state representation data wishing instruction expressing a position attainment state wishing instruction of a robot is made to memorize, An impaction efficiency stage wishing instruction of moving a robot to a position wishing instruction by movement controls of a robot by this control means, and a teaching-positions storage step which makes a control means memorize instruction positional data are included.

[0006]And it is the important feature of this invention that an autonomous movement execution phase made to carry out to this impaction efficiency stage wishing instruction autonomously based on position attainment state representation data wishing instruction which had movement in a position wishing instruction memorized is included.

[0007]In order to make it possible, this autonomous movement position attainment state representation data wishing instruction, It is acquired through seeing from a visual sensor

expressed using a visual target means which can be recognized with a visual sensor, and said visual sensor recognizing a position attainment equivalent state wishing instruction equivalent to a position attainment state wishing instruction.

[0008]A visual target means is used in an autonomous movement stage as a guidance visual target means for showing a robot to said position wishing instruction through being recognized by a visual sensor.

[0009]Software processing performed within a control means for autonomous movement is performed so that a recognition state of a guidance visual target means by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction and a robot may be derived. The visual target means can take a gestalt of a mark means including a mark coordinate system which can be recognized with a visual sensor. In that case, data showing a position and a posture of a mark coordinate system on a picture will be contained in position attainment state representation data wishing instruction memorized by a position attainment state storage step wishing instruction. On the other hand, this mark means is used in order to prepare a mark coordinate system for a position with fixed in order to provide a guidance visual target means for autonomous movement of a robot relative relation as a position wishing instruction. And a robot is derived so that a recognition state of a mark coordinate system by a visual sensor may be in agreement with a recognition state corresponding to position attainment state representation data wishing instruction by movement controls based on software processing performed within a control means.

[0010]A mark member fixable on a field of a representation work made into an object of teaching work can be used for a mark means. On this mark member, a mark coordinate system is drawn by a dot pattern etc.

[0011]There is light spot formed on a floodlighting side of an optical beam light projection means supported by robot as a gestalt of another available visual target means. When using such light spot as a visual target means, in order to prepare a position attainment equivalent state wishing instruction to a visual sensor in a position attainment state storage step wishing instruction, it is an instruction target point (a point which it is going to coincide with a position wishing instruction) of a robot about light spot. Usually, it is tool point;TCP. A reference floodlighting side for forming in a position in agreement is arranged.

[0012]The optical beam floodlighting direction is adjusted and light spot is formed in an instruction target point position on this reference floodlighting side. This state is equivalent to a teaching-positions attainment equivalent state for a visual sensor. Then, light spot is recognized by a visual sensor, and position attainment state representation data wishing instruction is acquired so that data showing a position on a picture of light spot may be included.

[0013]An autonomous movement stage is performed where the optical beam floodlighting direction which removed a reference floodlighting side and was seen from a camera in a position attainment equivalent state wishing instruction is maintained. That is, movement controls of a robot in an autonomous movement execution phase are performed, using light spot which floodlights an optical beam and is formed on a field where a position wishing instruction exists as a guidance visual target means. Software processing for movement controls of a robot is performed so that a recognition state of light spot by a visual sensor may be in agreement with a recognition state corresponding

to position attainment state representation data wishing instruction and a robot may be derived.

[0014]In advance of autonomous movement to a position wishing instruction, it may be made to jog in order to perform preliminary approach to a position wishing instruction. As for shift to an autonomous movement stage from a jogging stage, in that case, it is preferred to be automatically carried out by the processing within a control means based on an output of a visual sensor.

[0015]Software processing in an autonomous movement execution phase to a position wishing instruction, Processing which compares with position attainment state representation data wishing instruction data showing a position on a picture of a guidance visual target means recognized by a visual sensor at the time concerned, Suppose that processing for carrying out the movement controls of each axis of a robot based on a comparison result and processing which judges completion / un-completing of a position attainment state wishing instruction are repeated sequentially until a judgment of position attainment state completion wishing instruction is made.

[0016]Data of a position on a picture of a visual target means observed in this invention when a position wishing instruction is reached is inputted beforehand, and at the time of autonomous movement to a position wishing instruction. A visual target means is used like a navigation index of robot movement by observing with a visual sensor, and a robot is made to turn and derive to a position wishing instruction.

[0017]By this feature, a position attainment state wishing instruction is attained efficiently, without applying a burden to an operator. The highly convenient nature of a robot at the time of position teaching work can also be further raised by performing shift to autonomous movement from jogging with the automatic change in a system. Therefore, even when a large number [the number of positions wishing instruction], there are few burdens of teaching work and they end.

[0018]

[Embodiment of the Invention]Drawing 1 is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention. The numerals 1a express the position attainment state representation data input means wishing instruction which inputs the data expressing the position attainment state wishing instruction. This position attainment state representation data input means 1a wishing instruction, Visual target B1 Data expressing the relative physical relationship of the visual target B1 in the state where movement in the position wishing instruction of the robot [/ else] 2 was completed, and the robot hand 2a. (it is hereafter called "the position attainment state representation data wishing instruction".) -- it has the function to input into the memory 4 beforehand.

[0019]The position wishing instruction is illustrated by the four numerals A1 on the field 3a of the representation work 3 - A4. B1 drawn A1 - near each [of A4] - B4 are given by the position A1 wishing instruction - A4 representing the position which A1 - A4 express which are visual target means and each correspond, and a fixed relation. The example of a visual target means is mentioned later. In the usual gestalt, each visual target position B1 - B4 and each position A1 wishing instruction - A4 are given so that coincidence may not be carried out, although it is close, but they can also coincide both depending on the case.

[0020]The numerals 2a and 2b express the end point position and instruction target point

(usually tool point; TCP) of the robot respectively. In the following explanation, the end point position 2a of a robot shall be represented with the starting point of the coordinate system set up on the flange at the tip of a final arm.

[0021]An operator operates the robot manual operation means (robot motion instruction manual input means; teaching control panel etc.) 5, such as a jogging button, makes the shaft movement control means 6 control each axis of the robot 2, and makes movement in the position wishing instruction start in the time of actual work. The movement controls for autonomous movement in the position wishing instruction from the time of this move start or a certain point in time after a move start are performed. The position attainment state representation data wishing instruction into which the movement controls for this autonomous movement were inputted by the position attainment state representation data input means 1a wishing instruction, It is carried out based on the relative-position-recognition data showing the relative physical relationship between the robot hand and visual target means (camera fixed to this) at each time.

[0022]The latter data is given once [at least] in the process of movement controls by the relative-position-recognition means 1b between robot hand visual targets. in the position attainment state wishing instruction -- naturally -- TCP2b -- the position wishing instruction -- one is in agreement with A1 (or A2 - A4 one) (it illustrates by numerals 2b').

[0023]The position attainment state representation data input means 1a wishing instruction and the relative-position-recognition means 1b are materialized in the form where a visual sensor is used so that it may mention later. The visual target means B1 - B4 are materialized in the form of the light spot formed of the mark coordinate system or laser beam which can be recognized with a visual sensor. In the following explanation, the gestalt which materializes a visual target means in the form of a mark coordinate system is called "the method 1", and the gestalt materialized in the form of the light spot formed of a laser beam is called "the method 2."

[0024]drawing 2 showed the outline of the hardware constitutions of the system used by this embodiment with the important section block diagram centering on a robot control device -- it is. The robot control device to which the whole was directed with the numerals 30 was equipped with the processor board 31, and this processor board 31 is provided with the central processing unit (henceforth CPU) 31a, ROM31b, and RAM31c which consist of microprocessors.

[0025]CPU31a controls the whole robot control device according to the system program stored in ROM31b. A program, a related preset value, etc. which defined the processing by the side of a robot required to perform autonomous movement to the position wishing instruction else [, such as a created operation program and various preset values,] according to the method 1 or the method 2 are stored in RAM31c. A part of RAM31c is used for temporary data storage for the computation etc. which CPU31a performs. The hard disk drive etc. which were suitably prepared as an external device are used for preservation of program data or a preset value.

[0026]The processor board 31 is combined with the bus 37, and instructions and transfer of data are performed among other portions in the robot control device 30 via this bus combination. First, the digital-servo control circuit 32 is connected to the processor board 31, and the servo motors 51-56 are driven via the servo amplifier 33 in response to the instructions from CPU31a. The servo motors 51-56 which operate each axis are built in

the mechanism part of each axis of the robot 2.

[0027]The serial port 34 having a communication interface is connected to the teaching control panel 40, the image processing device 20, and the laser generator 60 with a liquid crystal display section while being combined with the bus 37. However, the laser generator 60 is used by the method 2, and is unnecessary in the method 1.

[0028]The teaching control panel 40 has the size and weight which are the grades whose carrying is possible with an operator, and the jogging button etc. which are used as a robot manual operation means are provided on the panel. In addition, the input/output device 35 for digital signals (digital I/O) and the input/output device 36 for analog signals (analog I/O) are combined with the bus 37. When signal transfer with an end effector is required, the control section of an end effector is connected to digital I/O35 or analog I/O36. In the example mentioned later, since the arc welding robot's application is considered, the electric power unit of an arc welding torch is connected to digital I/O35.

[0029]The image processing device 20 is the usual thing which made CPU carry out bus combination of program memory, a frame memory, an image processing processor, data memory, the camera interface, etc. The camera 21 is connected to the image processing device 20 via the camera interface. This camera is used for the photography for acquiring the picture of a visual target means in the mode mentioned later. The program data for image analyses needed by the method 1 or the method 2 is stored in program memory.

[0030]Drawing 3 is a figure showing the outline composition of the panel surface of the teaching control panel 40. The display screen 41 is a liquid crystal display, and the detailed data of a movement command program, etc. change it, and it is displayed. The function key 42 is a key which selects the menu displayed on the lower end part of the display screen 41. The teaching control panel effective switch 43 is a switch which switches whether operation of the teaching control panel 40 is effective or invalid.

[0031]The emergency stop button 44 is a button to which the emergency stop of the operation of the robot 2 is carried out. The cursor key 45 is a key which moves the cursor displayed on the display screen 41. A numerical keypad and other keys are provided in the ten key part 46, and input of a numerical value and a character, deletion, etc. can be performed to it.

[0032]Although a series of jogging buttons 47 (J1-J6) are buttons which specify advancing side by side / hand of cut, and the direction of +-, and input a movement command in the normal mode which jogs a conventional system, According to this embodiment (autonomous movement mode), it is used as an autonomous movement command input means to the position wishing instruction so that it may mention later. The details of an embodiment are explained below about the method 1 and the method 2 on the assumption that the above matter.

[0033][Method 1]

[1] The schematic diagram 4 is a figure explaining operation of the autonomous movement in the embodiment by the method 1. On the field 3a of the representation work directed with the numerals 3 as well as drawing 1, a number (here four pieces) corresponding to the number of the teaching points A1 - A4 to wish of mark members MK1-MK4 are stuck. On each mark member, the same mark coordinate system is drawn by the dot pattern so that it may mention later. Mark member MK1 is stuck by the position and the posture in which it corresponds to the position and posture of the point A1 wishing [instruction] correctly. Similarly, the mark members MK2-MK4 are stuck

by the position and the posture in which it corresponds to the point A2 wishing [instruction] - the position and posture of A4 correctly respectively.

[0034]The robot which carried out representation only of the hand part circumference carries the welding torch 2c and the camera 21 in the hand part, and TCP2b is set up at the tip of welding torch 2c. By this embodiment, a robot is left from the move starting position Ps, autonomous movement of the TCP2b set up at the tip of the welding torch 2c is carried out to the point A1 wishing [instruction] - A4 one by one, and the case where position instruction is performed in each position wishing instruction is considered. Generally the starting position Ps of autonomous movement is arbitrary, if mark MK1 of the beginning is a position included in the view of the camera 21.

[0035]Drawing 5 is a figure explaining the composition of the mark member used by the embodiment by the method 1. Reference of the figure constitutes mark coordinate system sigmaM from the five circular dots D0 arranged in the shape of a lattice by the interval a on the mark member MK, D1, D-1, D2, and D-2. Dot space a is positive constant value. Therefore, the center position of each dot is set to D0 (0, 0, 0), D1 (a, 0, 0), D-1 (- a, 0, 0), D2 (a, a, 0), and D-2 (- a, a, 0). As long as it can express a three-dimensional rectangular coordinate system, a mark coordinate system may consist of other patterns.

[0036]Hole MH is provided in the regular position where the mark member MK is suitable. This hole MH points to the position wishing instruction, and when sticking on the field 3a of the representation work 3, a sticking position is chosen so that that representative point (for example, center) may be in agreement with the position wishing instruction. A pasting posture is chosen with reference to direction of mark coordinate system sigmaM. That is, if pasting postures differ, the postures taught later also differ. For example, since the pasting posture of MK1 and MK4 in drawing 4 is different 90 degrees, it becomes what differed also in the posture taught later 90 degrees.

[0037][2] Preparation (the calibration of a camera, and acquisition of the position attainment state representation data wishing instruction)

1. Perform the calibration of the camera with the application of suitable calibration method in advance of working starting. Although various techniques are known by the calibration of the camera, the mark member shown here can also be used. The outline is described on the convenience of explanation, and in the back.

[0038]2. Perform acquisition of the position attainment state representation data wishing instruction. First, the mark member MK is fixed to a suitable position. Of course, one of the mark members stuck on the representation work 3 can also be used as it is. First, by jog operation of the normal mode (conventional system), a robot is moved, tool point 2b is coincided with representative point MA of hole MH of the mark member MK, and it is made to take the posture wishing instruction. It means that the position attainment state wishing instruction was realized about the mark member MK by this.

[0039]3. If the position attainment state wishing instruction is realized about the mark member MK, photography with the camera 21 will be made to perform via the robot control device 30, and the picture for creating the position attainment state representation data wishing instruction will be acquired.

4. Image processing of the acquired picture is carried out within the image processing device 20, and the data showing the relative positional attitude of mark coordinate system sigmaM to the camera coordinate system of the camera 21 is created (it mentions later for details).

[0040][3] Start movement in the position wishing autonomous instruction from the approach starting position Ps (it expresses in a flange position) shown in processing drawing 4 at the time of the position autonomous movement wishing instruction in the method 1, and explain the algorithm of the processing for attaining movement in the position Pt (it expresses in a flange position) wishing instruction. In the following explanation, since a vector is expressed, sign <> is used.

1. Skeleton drawing 7 of an algorithm describes the skeleton of an algorithm required for movement in the autonomous position wishing instruction. The current position (position at each [under movement in the position wishing instruction] time) T0 of a flange, and the present relative position (relative position at each [in the moving process to the position wishing instruction] time) M0 of a camera coordinate system and a mark coordinate system, As [describe / the geometric relation with the flange position Tg and relative-position (target relative position) Mg of a camera coordinate system and a mark coordinate system in the position attainment state wishing instruction in the position attainment state wishing instruction / into drawing 4]

[0041] And Mg is equivalent to the position attainment state representation data wishing instruction acquired by the above-mentioned preparatory work. C is taught by a camera calibration. The fundamental equation which specifies the relation between these [T0], M0, Tg, and Mg is as follows.

$T0 \cdot CM0 = Tg \cdot CMg \dots (1)$, therefore the following formula (2) which solved this about Tg turn into a basic equation showing the moving-target position on the rectangular coordinate system of a robot.

$$Tg = T0 \cdot CM0 \cdot Mg^{-1} \cdot C^{-1} \dots (2)$$

If the position instruction which makes this Tg a final moving-target point is given to a servo, a robot can be turned to the position wishing instruction and can be moved autonomously. Therefore, defining the algorithm of the autonomous movement to the position wishing instruction results in the problem which asks for the right-hand side of (2) types concretely.

[0042](2) Among the right-hand side of a formula, T0 expresses the present position data of the robot, and is data of the character obtained within a robot control device at any time. The data of C is separately gained by a suitable camera calibration (the example of a calibration is mentioned later). Then, it explains from how to calculate M0 and Mg.

[0043] 2. Each of equations M0 of M0 and Mg and Mg expresses the position and the posture of mark coordinate system sigmaM seen from the camera coordinate system (at the time of the completion of the present and approach).

[0044] Since it is positive constant value, the arrangement interval a of the circular dots D0 which constitute mark coordinate system sigmaM (refer to drawing 5) used by this embodiment, D1, D-1, D2, and D-2 is $a > 0 \dots$ It is (3). M0 and Mg are the homogeneous transformation processions of 4x4 expressing the relation between the position and posture between three-dimensional rectangular coordinate systems, and can be placed like a following formula (4).

[0045]

[Equation 1]

$$M = \begin{bmatrix} RM & tM \\ t_0 & 1 \end{bmatrix} \dots (4)$$

Here, 3x3 processions for which RM expresses rotation, and lM are 3x1 processions (vector) showing a position. It considers asking for the equation which RM and lM fill hereafter as an equation which M0 and Mg fill. First, the following formula (5) and (6) defines a vector <e1> and <e2>.

[0046]

[Equation 2]

$$\langle e1 \rangle = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \quad \dots (5)$$

$$\langle e2 \rangle = \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} \quad \dots (6)$$

As for the information acquired from a visual sensor about mark coordinate system sigmaM, the center of each circular dots D0, D1, D-1, D2, and D-2 aims (sight line direction) to be in sight from the starting point of a camera coordinate system. These directions can be expressed with five unit vectors <d0>, <d1>, <d-1>, <d2>, and <d-2> as shown in drawing 6.

[0047]deltaij defined by the following formula (7) is introduced about the inner product of these vectors.

deltaij=<di>- <dj> (i, j=-2, -1, 0, 1, 2) ... (7) -- here, since all the length of <d0>, <d1>, <d-1>, <d2>, and <d-2> is 1, the absolute value of deltaij does not exceed 1.

|deltaij|<=1 (a necessary and sufficient condition for equal mark formation is i=j) --- (8)

Although distance from the camera coordinate system starting point to each dot center is unknown, this is placed with ti (i=-2, -1, 0, 1, 2). Naturally these take a positive value.

[0048]

ti >0 (i=-2, -1, 0, 1, 2) ... If (9) is carried out, following equation (10) - (12) will be obtained.

t0 <d0> =lM ... (10) t1 <d1> =lM+aRM <e1> ... (11a)

t-1 <d-1> =lM -aRM <e1> ... (11b)

t2 <d2> =t1 <d1>+aRM <e2> ... (12a)

t-2 <d-2> =t-1 <d-1>+aRM <e2> ... (12b)

Therefore, if an equation of these is solved about RM and lM and it goes, calculating ti, M0 and Mg can be defined. A concrete solution will be explained by a paragraph of how to calculate 4.M0 and Mg, and C showing a position and a posture of a camera coordinate system is described briefly.

[0049]3. The equation C of C is a procession expressing a position and a posture of a camera coordinate system seen from a flange, and the data is obtained by calibration of the camera 21. Although various techniques are publicly known about a calibration and they can be used, even if it uses mark coordinate system sigmaM, a calibration of the camera 21 can also be performed. Here, only the main point is described briefly.

[0050]In three different points as shown with the numerals CB1-CB3 in drawing 4, photography with the camera 21 is performed respectively, image processing is performed and the data Pi (i= 1, 2, 3) about a relative position between the starting points of mark coordinate system sigmaM and a camera coordinate system is obtained. If data Ti (i= 1, 2, 3) of a robot position at the time of they and each photography is combined,

the following 3 sets of equations will be obtained. The point which calculates P_i ($i=1, 2, 3$) is the same as that of M_0 or M_g .

$$T_1 CP_1 = T_2 CP_2 = T_3 CP_3 \dots (13)$$

Under conditions from which three postures of a robot of CB_1 - CB_3 differ mutually, it is possible to solve this equation about C . This condition is set to (14).

Conditions: T_1 and T_2 differ from each posture ingredient of T_3 mutually. ... Data of C (14) Called for is memorized by a robot control device or image processing device.

About a solution of an equation, it explains supplementarily depending on how to ask for 5.C.

[0051]4. In M_0 and M_g asking, and solving equation (10) - (12) here and there, and calculating RM and IM , consider calculating t_i ($i=-2, -1, 0, 1, 2$) first. Therefore, a following formula (15) is replaced.

[0052]

[Equation 3]

$$\langle rM \rangle = \begin{bmatrix} rM_x \\ rM_y \\ rM_z \end{bmatrix} = RM^{-1} \langle IM \rangle \dots (15)$$

And equation (10) - (11) is transformed like following formula (16) - (18) using this.

$$\langle rM \rangle = t_0 RM^{-1} \langle d_0 \rangle \dots \langle rM \rangle + a \langle e_1 \rangle = t_1 RM^{-1} \langle d_1 \rangle \dots \langle rM \rangle - a \langle e_1 \rangle = t_{-1} RM^{-1} \langle d_{-1} \rangle \dots$$

(18) -- here, (17) (16) If RM^{-1} is cautious of it being a procession showing rotation, a following formula (19) will be materialized.

$(RM^{-1} \langle d_i \rangle) - (RM^{-1} \langle d_j \rangle) = \langle d_i \rangle - \langle d_j \rangle$ ($i, j=-2, -1, 0, 1, 2$) ... If this (19) (19) type, and (5) - (8) type and (16) - (18) type are used, following expression-of-relations (20) - (23) will be obtained.

[0053]

$$\| \langle rM \rangle \|^2 = t_0^2 \dots (20) \quad \| \langle rM \rangle \|^2 + 2 arM_x + a^2 = t_1^2 \dots (21a)$$

$$\| \langle rM \rangle \|^2 - 2 arM_x + a^2 = t_{-1}^2 \dots (21b)$$

$$\| \langle rM \rangle \|^2 + arM_x = t_0 t_1 \Delta_0 \text{ and } 1 \dots (22a)$$

$$\| \langle rM \rangle \|^2 - arM_x = t_0 t_{-1} \Delta_0 \text{ and } -1 \dots (22b)$$

$$\Delta_0, 1^2 < 1, \Delta_0, \text{ and } -1^2 < 1 \dots (23)$$

If it arranges carefully from these formulas for $\| \langle rM \rangle \|^2 + arM_x$, $\Delta_0, 1$ and $\| \langle rM \rangle \|^2 - arM_x$, and Δ_0 and -1 to become a same sign from conditions (3), (9), a formula (22a), and (22b) respectively, following formula (24a) - (25b) will be obtained.

[0054]

[Equation 4]

$$\| \langle rM \rangle \|^2 + arM_x = a \alpha + \sqrt{rM_y^2 + rM_z^2} \dots (24a)$$

$$\| \langle rM \rangle \|^2 - arM_x = a \alpha - \sqrt{rM_y^2 + rM_z^2} \dots (24b)$$

$$\text{但し、} \quad \alpha + = \frac{\text{def } \delta_{0,1}}{\sqrt{1 - \delta_{0,1}^2}} \dots (25a)$$

$$\alpha - = \frac{\text{def } \delta_{0,-1}}{\sqrt{1 - \delta_{0,-1}^2}} \dots (25b)$$

If a formula (24a) and (24b) change further, the following formula (26) and (27) will be obtained.

$\|< rM > \|^2 = (a^2 \beta_{+}^2) / (1 + \beta_{-}^2) \dots (26)$ $rM_x = (a \beta_{+} + \beta_{-}) / (1 + \beta_{-}^2) \dots (27)$ however β_{+} , and β_{-} shall be defined by a following formula (28a) and (28b).

$\beta_{+} = (\alpha_{++} + \alpha_{-}) / 2 \dots (28a)$

$\beta_{-} = (\alpha_{+-} - \alpha_{-}) / 2 \dots (28b)$

And if the formula (26) and (27) is substituted for the formula (20), (21a), and (21 b) and the conditions (3) and (9) are used, t_0 , t_1 , and t_{-1} can be found with the following formula (29), (30a), and (30b).

[0055]

[Equation 5]

$$t_0 = a \sqrt{\frac{\beta_{+}^2}{1 + \beta_{-}^2}} \dots (29)$$

$$t_1 = a \sqrt{\frac{1 + \alpha_{+}^2}{1 + \beta_{-}^2}} \dots (30a)$$

$$t_{-1} = a \sqrt{\frac{1 + \alpha_{-}^2}{1 + \beta_{-}^2}} \dots (30b)$$

t_2 , t_{-2} , $< lM >$, and RM are further calculated as follows using these.

[0056]

[Equation 6]

$$t_2 = \frac{t_1 - t_{1\delta 1, -1}}{t_{1\delta 1, 2} - t_{1\delta -1, 2}} t_1 \quad \dots (30c1)$$

($t_{1\delta 1, 2} - t_{1\delta -1, 2} \neq 0$ の場合)

$$t_{-2} = \frac{t_{-1} - t_{1\delta 1, -1}}{t_{1\delta -1, -2} - t_{1\delta 1, -2}} t_{-1} \quad \dots (30c2)$$

($t_{1\delta 1, 2} - t_{1\delta -1, 2} = 0$ の場合)

$$\langle IM \rangle = t_0 \langle d_0 \rangle \quad \dots (30d)$$

$$\langle RM \rangle = (\langle f_1 \rangle \langle f_2 \rangle \langle f_3 \rangle) \quad \dots (30e)$$

$$\text{但し、} \langle f_1 \rangle = \frac{1}{2a} (t_1 \langle d_1 \rangle - t_{-1} \langle d_{-1} \rangle) \quad \dots (30f)$$

$$\langle f_2 \rangle = \begin{cases} \frac{1}{a} (t_2 \langle d_2 \rangle - t_1 \langle d_1 \rangle) \\ \quad (t_{1\delta 1, 2} - t_{1\delta -1, 2} \neq 0 \text{の場合}) \quad \dots (30g) \\ \frac{1}{a} (t_{-2} \langle d_{-2} \rangle - t_{-1} \langle d_{-1} \rangle) \\ \quad (t_{1\delta 1, 2} - t_{1\delta -1, 2} = 0 \text{の場合}) \end{cases}$$

$$\langle f_3 \rangle = \langle f_1 \rangle \times \langle f_2 \rangle \quad \dots (30h)$$

5. Solve the above-mentioned equation (13) under the conditions (14) of the how [to ask for C] above-mentioned. Modification of an equation (13) will obtain the following (31) and (32).

$C^{-1}T_1^{-1}T_3 C = P_1 P_3^{-1} \dots C^{-1}T_2^{-1}T_3 C = P_2 P_3^{-1} \dots$ (32) -- replacement which followed following formula (33) - (37) here is performed. (31)

[0057]

[Equation 7]

$$\begin{bmatrix} R_c & I_c \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} C \quad \dots (33)$$

$$\begin{bmatrix} R_1 & I_1 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} T_1^{-1} T_3 \quad \dots (34)$$

$$\begin{bmatrix} R_2 & I_2 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} P_1 P_3^{-1} \quad \dots (35)$$

$$\begin{bmatrix} R_3 & I_3 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} T_2^{-1} T_3 \quad \dots (36)$$

$$\begin{bmatrix} R_4 & I_4 \\ t_0 & 1 \end{bmatrix} \stackrel{\text{def}}{=} P_2 P_3^{-1} \quad \dots (37)$$

Then, the equation (31) and (32) is decomposed into following equation (38) - (41).
 $RC^{-1}R_1 RC = R_2 \dots (38)$ $RC^{-1}R_3 RC = R_4 \dots (39)$ $\langle I-R_1 \rangle I_C = \langle I_1 \rangle - RC \langle I_2 \rangle \dots (40)$ $\langle I-R_3 \rangle I_C = \langle I_3 \rangle - RC \langle I_4 \rangle \dots (41)$

Therefore, it becomes a target to calculate RC and $\langle I_C \rangle$. Here, a form of an equation (38) and (39) shows that both similar transformation processions expressing the similarity R1 during a rotation procession - R2, R3 - R4, and those similarity relations are RC. Then, the following formula (42) and (43) is obtained considering a vector showing a hand of cut of Ri (i= 1, 2, 3, 4) as $\langle v_i \rangle$ (i= 1, 2, 3, 4). Here, $\langle v_i \rangle$ (i= 1, 2, 3, 4) can be uniquely defined from conditions (14), a definitional equation (34), and (36).

$$\langle v_1 \rangle = RC \langle v_2 \rangle \dots (42) \quad \langle v_3 \rangle = RC \langle v_4 \rangle \dots (43)$$

RC can be calculated if a relation of a following formula (44) is used.

$$(\langle v_1 \rangle, \langle v_3 \rangle, \text{ and } \langle v_1 \rangle \times \langle v_3 \rangle) = RC (\langle v_2 \rangle, \langle v_4 \rangle, \text{ and } \langle v_2 \rangle \times \langle v_4 \rangle) \dots \text{About (44) equations (40) and (41), a form of a following formula (45) is used at a bundle, and if a least-squares method is applied, } \langle I_C \rangle \text{ will be calculated.}$$

[0058]

[Equation 8]

$$\begin{bmatrix} 1 & -R_1 \\ 1 & -R_3 \end{bmatrix} \langle I_C \rangle = \begin{bmatrix} \langle I_1 \rangle \\ \langle I_3 \rangle \end{bmatrix} - RC \begin{bmatrix} \langle I_2 \rangle \\ \langle I_4 \rangle \end{bmatrix} \quad \dots (45)$$

6. Explain the outline of the process flow for movement in the preparatory work and the position wishing autonomous instruction in the method 1 on the assumption that the explanation item of beyond outline of process flow of movement controls by method 1 1.
- 5. First, it is as follows if supplemented about a preparatory work.
- (1) preceding working starting -- the above 3 -- as it came out and explained, move a robot to the three positions CB1-CB3 one by one.

(2) In each positions CB1-CB3, acquire the picture of mark coordinate system sigmaM (one piece) of mark member MK1 on the representation work 3, and acquire the data which expresses the sight line direction based on [each] dots by image processing in the image processing device 20.

(3) Perform processing according to the algorithm explained by above-mentioned 5. within the image processing device 20, and compute and memorize the data (data of RC and <IC>) of camera coordinate system C.

[0059](4) When a camera calibration is completed, move a robot to the position Pt shown in drawing 4, and make the position attainment state wishing instruction over mark MK1 appear.

[0060](5) Acquire a picture of mark coordinate system sigmaM and acquire data which expresses a sight line direction based on [each] dots by image processing in the image processing device 20.

(6) Perform processing according to an algorithm explained by above-mentioned 1.2.4. within the image processing device 20, and compute and memorize position attainment state representation data wishing instruction (data of Mg).

[0061]Autonomous movement in a position wishing instruction is performed by a processing cycle containing many following steps, as shown in a flow chart of drawing 8.

[K1] <d0>, <d1>, <d-1>, <d2>, and <d-2> are calculated by image processing, and M0 is calculated.

[K2] M0 calculated from <d0> calculated at data and Step K1 of Mg memorized, <d1>, <d-1>, <d2>, and <d-2> is compared, and both coincidence/disagreement are judged. If in agreement, since an attainment state to a position wishing instruction is meant, it progresses to Step K6. If inharmonious, since it means not having reached a position wishing instruction, it returns to Step K1 via Step K3 - K5. Various algorithms can be used for evaluation of the degree of coincidence of Mg and M0. for example, what is necessary is to compute the deciding index delta with a following formula (46), and just to suppose approach un-completing, if it is delta<epsilon (epsilon -- enough -- smallness - - a positive value) and is the completion of approach, and delta>=epsilon

[0062]

[Equation 9]

$$\Delta = \left\| \begin{pmatrix} Mo - Mg \\ 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \right\|^2 + \left\| \begin{pmatrix} Mo - Mg \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \right\|^2 + \left\| \begin{pmatrix} Mo - Mg \\ 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \right\|^2 + \left\| \begin{pmatrix} Mo - Mg \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \right\|^2 \dots (46)$$

[K3] The four-line procession T0 of four rows showing the position and posture of the hand (starting point of the coordinate system set up on the flange) of a robot is calculated and memorized.

[K4] Using the algorithm which explained [above-mentioned] with the data (data of C and Mg) acquired by the preparatory work, the right-hand side of (2) types is calculated and it asks for the perpendicular slip target position Tg.

[0063][K5] The movement command for going to the perpendicular slip target position Tg is created, a servo is passed, and a robot is moved. If the non-error of a system is

perfect, it should result in the position attainment state wishing instruction in the above step K1 - one cycle of K5, but the position attainment state wishing instruction is actually attained in successive approximations for the error of a visual sensor, the error of calculation, etc.

[0064][K6] A robot is stopped and processing is ended.

[Method 2]

[1] In the embodiment by the outline method 2, the light spot formed of a laser beam is used as a visual target means. First, drawing 9 - drawing 14 are added to a reference figure, and the outline of a preparatory work and teaching work is explained. Drawing 9 is a figure for explaining inner-1--3 of many stages of a preparatory work, and drawing 10 is a figure for explaining the remaining stages PR4-PR6. A figure for drawing 11 to explain inner TH1-TH3 of many stages of teaching work and drawing 12 are the figures for explaining stage TH4 and PR5.

[0065][2] Preparatory work (acquisition of position attainment state representation data wishing instruction, and calibration of a camera)

(PR1) a hand of a robot first represented with the flange position 2a -- the camera 21 -- in addition, the laser head 22 (irradiation head of the laser generator 60 shown in drawing 2) and the reference tool 25 are attached. The laser head 22 is attached via the suitable adjustment mechanism 23, and can adjust now the floodlighting direction of the laser beam 24. The mark 26 which expresses TCP (2b) with a portion shown by the arrow 27 near the tip of the reference tool 25 is formed. However, it needs to be cautious of this mark 26 being for viewing. Where the laser head 22 is attached, generally the laser beam 24 does not enter into the mark 26 on the reference tool 25, as illustrated.

[0066](PR2) Direction of the laser head 22 is adjusted and it is made for the laser beam 24 to enter into the mark 26 on the reference tool 25. Thereby, light spot is formed in a position of the mark 26, i.e., position 2b of TCP. The laser head 22 is henceforth fixed in this state.

[0067](PR3) Photography with the camera 21 is made to perform via the robot control device 30 in this state, and a picture for creating position attainment state representation data wishing instruction is acquired. Image processing of the picture of acquired light spot is carried out within the image processing device 20, and data showing the direction of light spot (it is in TCP position 2b.) seen from a camera coordinate system (starting point Oc) of the camera 21 of a vector $\langle et \rangle$ is created and memorized. This data is behind used as position attainment state representation data wishing instruction.

[0068](PR4) If data of $\langle et \rangle$ is acquired, the reference tool 25 will be removed. Since the laser head 22 is fixed, the laser beam 24 will pass along TCP (2b) in the air as illustrated.

[0069](PR5) Data of a vector $\langle eh \rangle$ is created and memorized as a vector showing the laser beam's 24 seen from the starting point Oc of camera coordinate system existence direction. $\langle eh \rangle$ is a vector by which the following two conditions are fulfilled.

Conditions 1; it is in a flat surface which a vector $\langle et \rangle$ and the laser beam 24 stretch.

It is a vector of a direction near a direction which looked at the laser head 22 from the camera 21 among $\langle eh(s) \rangle$ which fill condition 2; $\langle eh \rangle ** \langle et \rangle$. $\langle eh \rangle$ can be calculated by a method shown, for example in drawing 13.

[0070]That is, a robot is moved by jogging above the suitable flat surface (here, the representation work surface 3a is used.), and the spot F of the laser beam 24 is formed. And by approach to the field 3a of a robot from a state which has TCP position 2b above

the field 3a as shown in (1), as shown in (2), TCP position 2b makes the state of the field 3a of coming caudad. If it puts in another way, it will be made for a position of the spot F to come to an opposite hand from a state of (1) across the look 21a of the camera 21 and the intersection N of the field 3a which look at a TCP position (2b).

[0071] In this state, photography with the camera 21 is performed and a picture of the spot F is acquired. And image processing is performed within the image processing device 20, and it asks for data showing the direction of the spot F seen from a camera coordinate system of a vector <es>. A vector <eh> is computed with a following formula (47) using this <es>.

[0072]

[Equation 10]

$$\langle eh \rangle = \frac{\langle et \rangle \times \langle es \rangle}{\| \langle et \rangle \times \langle es \rangle \|} \quad \dots (47)$$

(PR6) The calibration of the camera 21 is performed. This is for asking for the relation of the flange coordinate system (2a is the starting point) and camera coordinate system which are set up on a robot hand's flange face. Various things are available as explanation of the method 1 described the technique of the KIKYA rib ration of a camera (the technique by a mark member may be used).

[0073][3] teaching work (TH1) by the method 2 -- move a robot first above the representation work surface 3a where the first position wishing instruction exists by jogging, and form the spot F of the laser beam 24 on the representation work surface 3a. Marking of the position A wishing instruction shall be beforehand carried out by the suitable teaching point mark A which can be recognized with a visual sensor. The flange position 2a in the state where it illustrated shall be set to Ps, and autonomous movement shall be started from the position Ps. Shift to autonomous movement from jogging can be considered as an automatic change which used a visual-sensor output, for example so that it may mention later.

[0074] TCP position 2b is above the field 3a, and the laser beam 24 forms the spot F on the field 3a through this point as illustrated. Generally in this stage TH1, three points are in another position mutually [the teaching point mark A and the spot positions F and TCP (2b)]. The look 21a which looked at the teaching point mark A from the camera 21 does not pass along TCP (2b).

[0075](TH2) A robot is operated by processing of autonomous movement and the look 21a which looked at the teaching point mark A from the camera 21 passes along TCP (2b). As operation of a robot, rotation of a circumference of the starting point Oc of a camera coordinate system is rational.

[0076](TH3) A robot is operated by processing of autonomous movement, and a formation position of the spot F is made to approach the teaching point mark A, keeping conditions by which the look 21a passes along TCP (2b) as much as possible. As operation of a robot, rotation of a circumference of Oc should be suitably combined with advance of the direction of look 21a.

[0077](TH4) If advance of the direction of look 21a becomes superfluous, while the look 21a will keep conditions which pass along TCP (2b) as much as possible, in accordance with the direction of look 21a, it retreats suitably, and rotation of a circumference of Oc is combined suitably.

[0078](TH5) Hereafter, operation (advance) of TH3 and operation of TH4 (retreat) are

repeated, and a formation position of the spot F is completed as the teaching point mark A. Since it is exactly an intersection of the look 21a which this convergent point passes along TCP (2b), and looks at the teaching point mark A, and a laser beam which passes along TCP (2b) therefore, it will come to the teaching point mark A and the position in which three points are the same as for the spot positions F and TCP (2b) after all. This means namely that instruction target point slack TCP (2b) reached a position wishing instruction. A position of flange position 2b at this time is expressed with Pt as well as a case of the method 1.

[0079] Then, if a robot position in this state is memorized to a control means (nonvolatile memory in a robot control device), position instruction of the position A will be completed. What is necessary is just to apply the above-mentioned processes TH1-TH5 about each teaching point mark of the 2nd henceforth, when there are two or more positions wishing instruction (teaching point mark) (see the point A1 - A4 on the representation work 3 in drawing 1, for example although a graphic display is omitted). [0080][4] Explain an algorithm of processing for attaining movement in the position Pt (similarly it expresses in a flange position) wishing instruction from the autonomous movement starting position Ps (it expresses in a flange position) according to a process explained by the processing above at the time of position autonomous movement wishing instruction in the method 2 [2]. Although sign $\langle \rangle$ expresses a vector as well as a case of the method 1, a definition content of a vector is separate from the method 1. Autonomous movement is performed based on a processing cycle according to an algorithm which described an outline in a flow chart of drawing 15 (L1-L12) and drawing 16 (L13-L19). Hereafter, it divides into each step and explains focusing on an algorithm. The meaning of many signs under explanation is as follows.

[0081] σ_0, σ_1 ; A value of 1 [**] is taken with a flag with which all express advance/retreat of a robot. +1 means advance and -1 means retreat.

l ; register value [showing the amount of units of advance/retreat of a robot] $\langle dm \rangle$; -- to have been shown in drawing 14 is asked from image data by a unit vector (length 1) showing a sight line direction which looked at the teaching point mark A from the starting point Oc of a camera coordinate system.

$\langle ds \rangle$; to have been shown in drawing 14 similarly is asked from image data like $\langle dm \rangle$ by a unit vector (length 1) showing a sight line direction which looked at spot position F (incidence position of the laser beam 24) from the starting point Oc of a camera coordinate system.

[0082] T; procession deltar which expresses a position and a posture of a robot on a robot-coordinates system, Δ ; Positive constant near [in a threshold with suitable all] 0. What expresses the minimum rotation with a rotation procession which describes a relation of the direction of R; $\langle dm \rangle$ and $\langle et \rangle$ among 3x3 processions used as $R \langle et \rangle = \langle dm \rangle$.

sgn; it defines as signum as follows.

$\text{sgn}(x) = +1 \ (x > 0)$

$\text{sgn}(x) = 0 \ (x = 0)$

$\text{sgn}(x) = -1 \ (x < 0)$

[L1] Flag σ_0 is initialized to 1. l is initialized to a suitable initial value (for example, 3 cm).

[L2] A register value showing data of the procession T is updated based on a current

position of a robot.

[L3] A photograph is taken using the camera 21 and it tries to search for a vector <dm> using the image processing device 20.

[L4] Since it is possible that the teaching point mark A is not caught with a camera view if a vector <dm> is not searched for, processing is ended (an operator is changed into the state where adjust a robot position by jogging and the teaching point mark A is certainly caught with a camera view). When a vector <dm> is searched for, it progresses to Step L5.

[0083][L5] It asks for an outer product of a vector <et> and a vector <dm>, and <dr>=[>] <et> x <dm>.

[L6] As compared with threshold deltar, if not small, he follows an absolute value of a vector <dr> to Step L7. If small, it will progress to Step L10.

[0084][L7] The rotation procession R which describes a relation of the direction of <dm> and <et> is computed by a declared formula. A declared formula is obtained by solving the following simultaneous equations about R.

$R \langle et = [\rangle \langle dm \rangle \dots (48)$

$R \langle dr = [\rangle \langle dr \rangle \dots (49)$

[L8] A register value showing data of the procession T is updated to a thing to a procession of a notation containing the new submatrix R. This procession solves the following equation (50) about Tg, and is set to Tg ->T.

[0085]

[Equation 11]

$$T_g C = T C \begin{bmatrix} R & 0 \\ t_0 & 1 \end{bmatrix} \dots (50)$$

[L9] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L8 expresses is performed, and it returns to Step L2.

[L10] By step L6, if it is judged that the absolute value of a vector <dr> is smaller than threshold deltar, this step L10 will be performed for the first time. It tries to search for the unit vector <ds> which expresses with this step the sight line direction which looked at spot position F from the starting point Oc of the camera coordinate system from image data.

[0086][L11] It is thought that it cannot happen that the spot F is not settled in a camera view when [this] an absolute value of a vector <dr> is about 0 (a look which looks at TCP, and a look which looks at a teaching point mark are real coincidence) unless there are a system abnormality, a design error, etc. Therefore, in almost all cases, a vector <ds> is searched for and it progresses to Step L12. However, processing is ended if <ds> should not be calculated (a cause inquiry etc. are performed separately).

[0087][L12] <ds> and <et> are the real same directions, and it confirms whether to be the inner product 1 (it is cautious of deltal being a very small positive value).

[L13] Flag signal1 showing advance/retreat of a robot will be set to signal1 =0, if an inner product of <ds> and <eh> is positive, it is signal1 =-1 and negative and it will become signal1 =1 and a real target zero.

[L14] If it is signal1 =0, it will progress to Step L15. If it is not signal1 =0, it will progress to Step L16.

[L15] signal1 is updated to sigma0 and it progresses to Step L18.

[L16] If a product of sigma1 and sigma0 is positive, it will progress to Step L18. If it is negative, it will progress to Step L17.

[0088][L17] A value of 1 is reduced by half while updating sigma0 to sigma1.

[L18] A register value showing data of the procession T is updated to a thing to a declared procession. This procession solves the following equation (51) about Tg, and is set to Tg -> T.

[0089]

[Equation 12]

$$T_g C = T C \begin{bmatrix} 1 & \sigma 1 l < e t > \\ t_0 & 1 \end{bmatrix} \dots (51)$$

[L19] A robot is operated, processing for making it move to the position and posture which the procession T calculated at Step L18 expresses is performed, and it returns to Step L2.

In the processing cycle according to the algorithm explained above, if the judgment output of yes is obtained at Step L12 at one of the times, it will be understood as the position attainment state wishing instruction as shown in (TH5) of drawing 12 having been realized, a robot will be stopped, and processing will be ended.

[0090]As mentioned above, since movement in the position wishing instruction of a robot will be autonomously performed so that it may become the position of a position attainment state wishing instruction and the posture which it was inputted beforehand if this invention is followed so that I may be understood from the explanation about the embodiment of the method 1 and the method 2, working efficiency improves.

[0091]the method 1 and the method 2 -- also in which embodiment, it is preferred to automate a change in the mode of autonomous movement in which it tends toward a position wishing instruction autonomously, from the mode of jogging by a manual command input by processing inside a control means (the robot control device 30 and the image processing device 20).

[0092]Drawing 17 shows an operating procedure of a teaching control panel, and outline of processing with a flow chart about a case where a change in the mode of autonomous movement of jogging from the mode is performed inside a system. It is as follows when processing of each step is described briefly. An output of a visual sensor is used for determination of timing of a mode change in this example.

[S1] If it judges whether the jogging button 47 (any one) was pushed and instructions of jogging were made, and are made, will progress to Step S2 and it will not be made, Step S1 is repeated.

[S2] According to movement contents (a direction, an axis, etc.) specified with the jogging button 47, a predetermined axis is controlled and jogging movement of the robot 10 is started. For example, if movement of the direction of J6 axis + is specified, a movement command which advances J6 axis in the direction of + will be created, and a servo will be passed.

[S3] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 will not be progressed and used, it progresses to step S4.

[S4] If existence of reception of a signal which tells that the teaching point mark A (a case of the method 2 and the spot F) entered in a view of the camera 13 was checked, it has received and it will not have progressed and received to Step S5, it returns from the

image processing device 20 to Step S3.

[S5] Processing of autonomous movement is started. It is as having divided into the method 1 and the method 2 and having mentioned above about an example of the concrete contents of processing.

[S6] It judges whether the jogging button 47 was turned OFF, and if are turned OFF and Step S8 is not progressed and used, it progresses to Step S7.

[S7] It judges whether it reached to a position wishing instruction, if it has reached, it will progress to Step S8, and if it has not reached, it will return to Step S6. It is as having also described a judgment method which is not reached [the position attainment wishing instruction /] in explanation of the method 1 and the method 2.

[S8] Operation of each axis of the robot 2 is stopped.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is a figure which illustrates notionally the overview of the movement control system for the position instruction of a robot according to this invention.

[Drawing 2]the important section block diagram centering on a robot control device showed the outline of the hardware constitutions of the system used by this embodiment - it is.

[Drawing 3]It is a figure showing the outline composition of the panel surface of the teaching control panel 40.

[Drawing 4]It is a figure explaining operation of the autonomous movement in the embodiment by the method 1.

[Drawing 5]It is a figure explaining the composition of the mark member used by the embodiment by the method 1.

[Drawing 6]In the embodiment by the method 1, a camera is a figure explaining the vector which describes the sight line direction which looks at a mark coordinate system.

[Drawing 7]It is a figure explaining the outline of an algorithm required for the position autonomous movement wishing instruction in the embodiment by the method 1.

[Drawing 8]It is the flow chart which described the outline of processing of the position autonomous movement wishing instruction in the embodiment by the method 1.

[Drawing 9]It is a figure for explaining inner-1--3 of many stages of the preparatory work in the embodiment by the method 2.

[Drawing 10]It is a figure for explaining inner-4--6 of many stages of the preparatory work in the embodiment by the method 2.

[Drawing 11]It is a figure for explaining inner TH1-TH3 of many stages of the teaching work in the embodiment by the method 2.

[Drawing 12]It is a figure for explaining inner TH4 of many stages of the teaching work in the embodiment by the method 2, and TH5.

[Drawing 13]In the embodiment by the method 2, it is a figure explaining how to search for a vector <eh>.

[Drawing 14]It is a figure which illustrates a vector <dm> and <ds> about the embodiment by the method 2.

[Drawing 15]It is the first half (L1-L12) of a flow chart in which the outline of the

algorithm of processing for control of the autonomous movement in the embodiment by the method 2 was described.

[Drawing 16] It is the latter half (L13-L19) of the flow chart which described the outline of the algorithm of processing for control of the autonomous movement in the embodiment by the method 2.

[Drawing 17] In the embodiment by the method 1 or the method 2, a flow chart shows the operating procedure of a teaching control panel, and the outline of processing about the case where the change in the mode of autonomous movement of jogging from the mode is performed inside a system.

[Description of Notations]

1a The position attainment status input means wishing instruction

1b The relative-position-recognition means between robot hand visual targets

2 Robot

2a Flange representative point (flange coordinate system starting point)

2b Instruction target point (TCP; tool point)

The instruction target point (TCP) which reached the position wishing 2b' instruction

3 Representation work

4 Memory

5 Robot manual operation means

6 Shaft movement control means

20 Image processing device

21 Camera

22 Laser head (irradiation part of a laser generator)

23 The floodlighting direction control function of a laser head

24 Laser beam

30 Robot control device

31 Processor board

31a Processor

31b ROM

31c RAM

35 Digital I/O

36 Analog I/O

37 Bus

40 Teaching control panel

41 Display screen

42 Function key

44 Emergency stop button

45 Cursor key

46 Ten key part

47 (J1-J6) jogging button

51-56 Servo motor

60 Laser generator

A Teaching point mark (position wishing instruction)

A1 - A4 Position wishing instruction

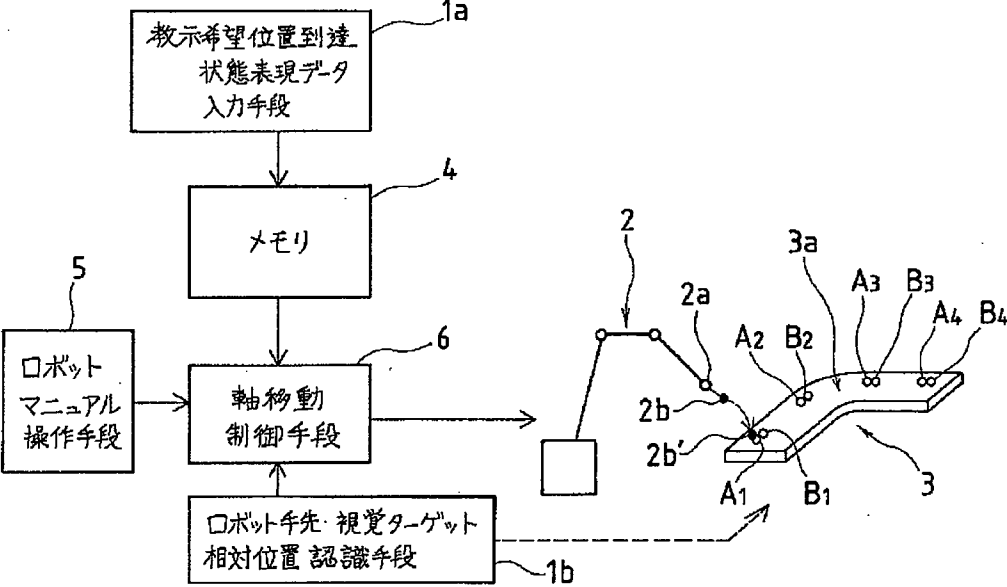
B1 - B4 visual target means

CB1-3 Position which performs the calibration of a camera

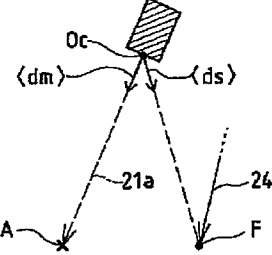
The dot of D0, D1, D-1, D2, and D-2 mark coordinate system
F Spot
MK1-MK4 Mark member
sigmaM mark coordinate system

DRAWINGS

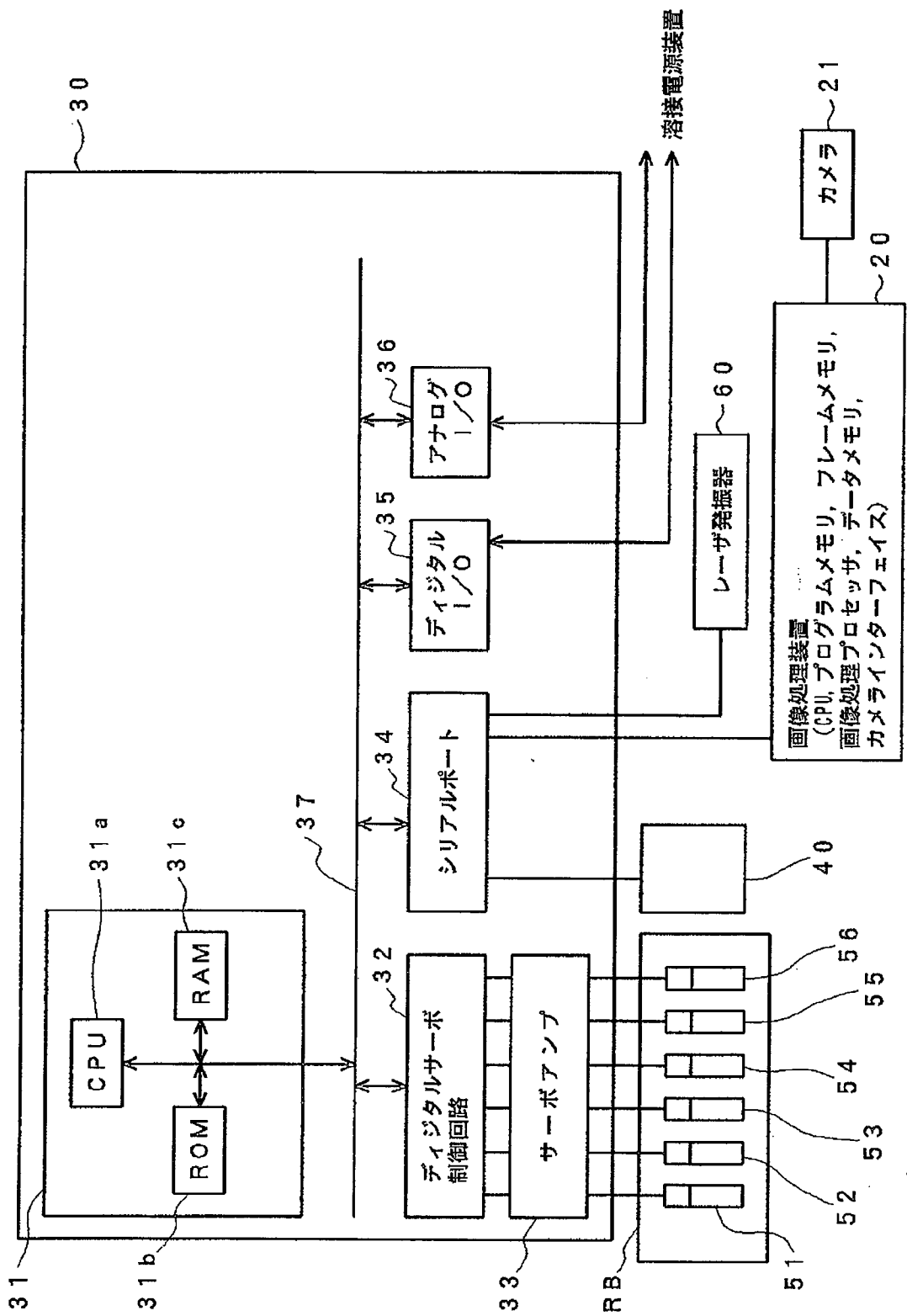
[Drawing 1]



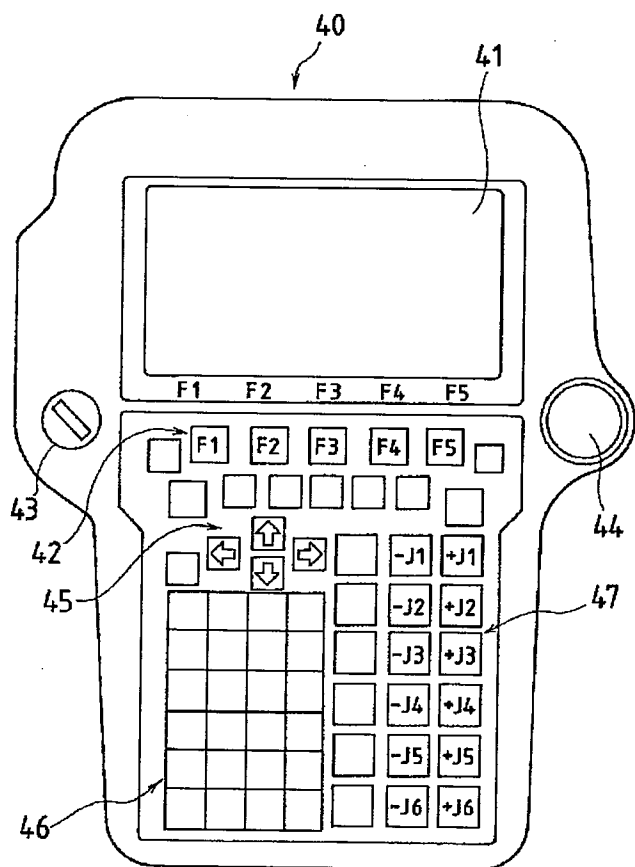
[Drawing 14]



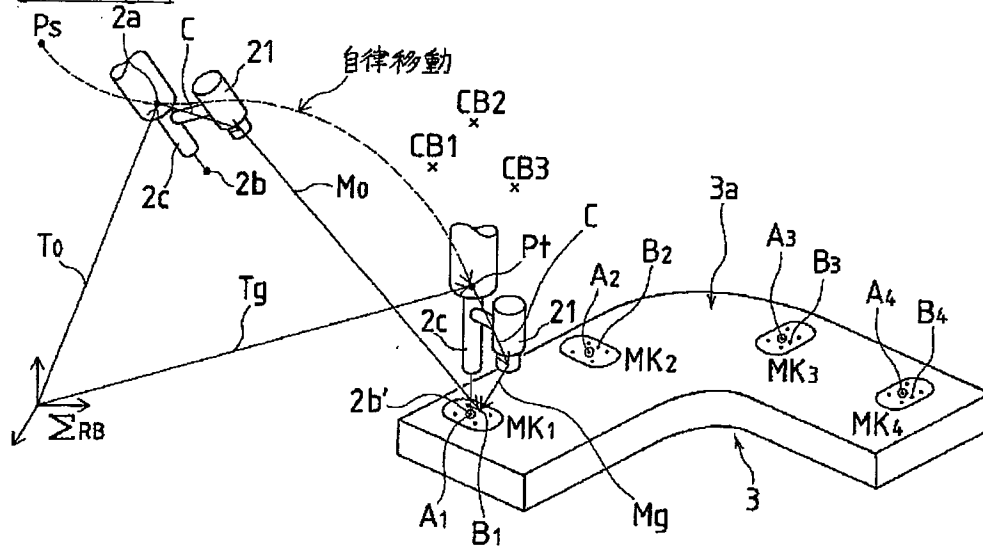
[Drawing 2]



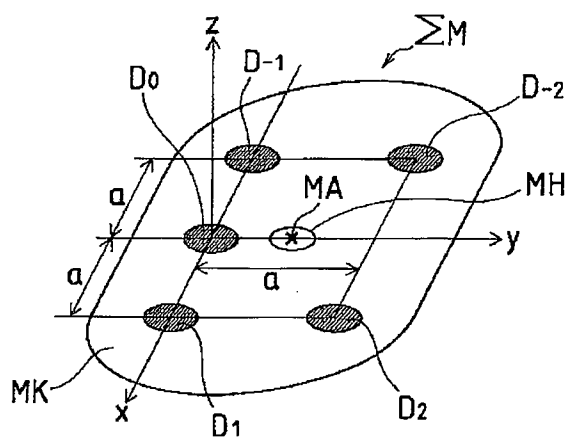
[Drawing 3]



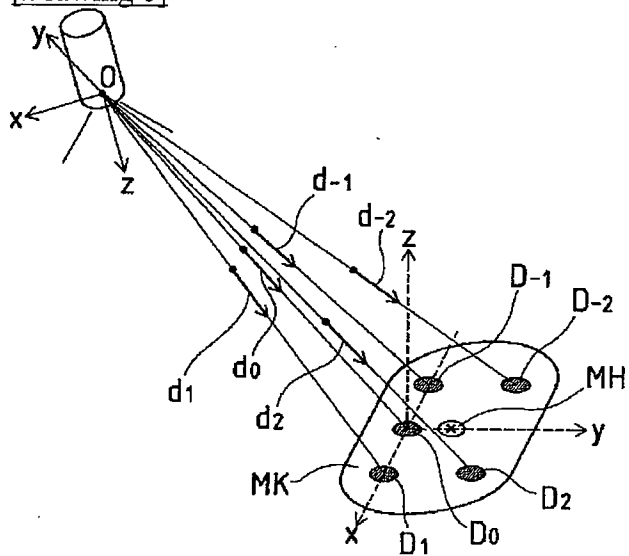
[Drawing 4]



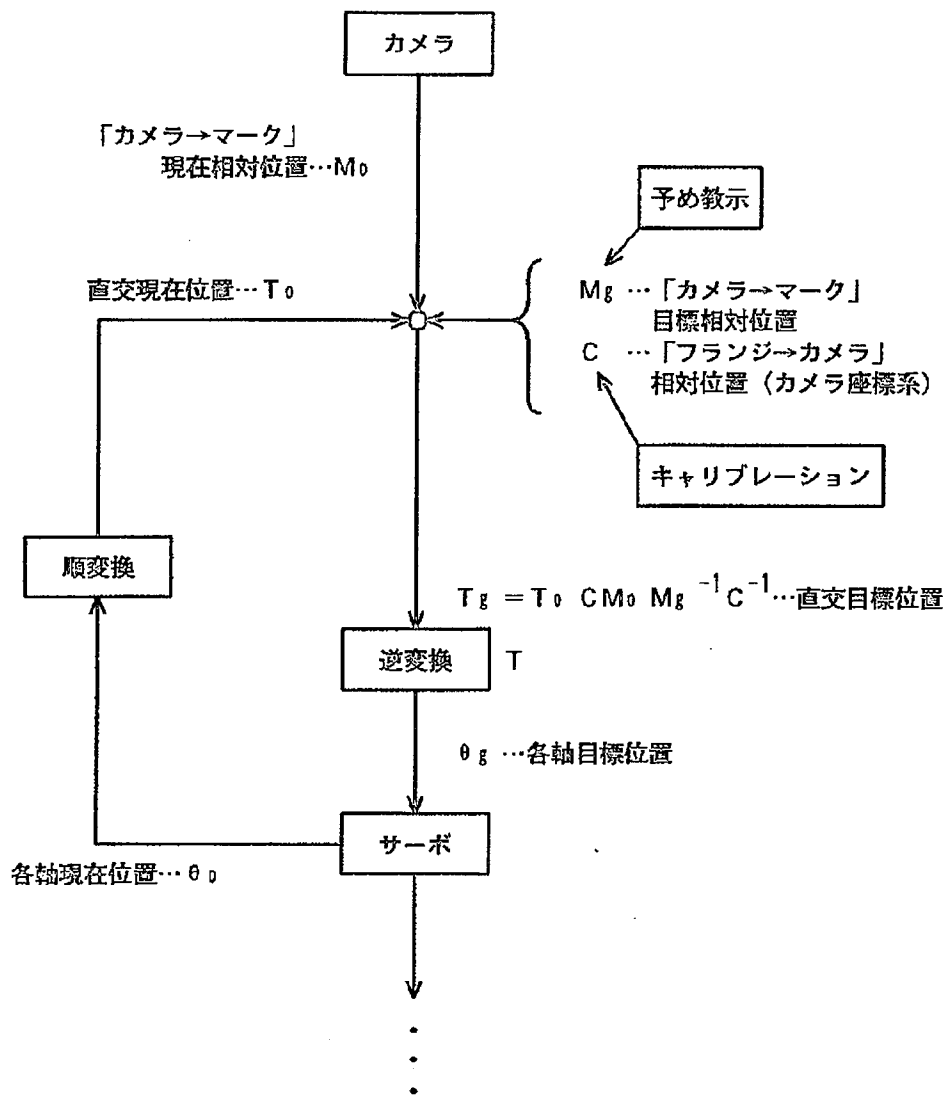
[Drawing 5]



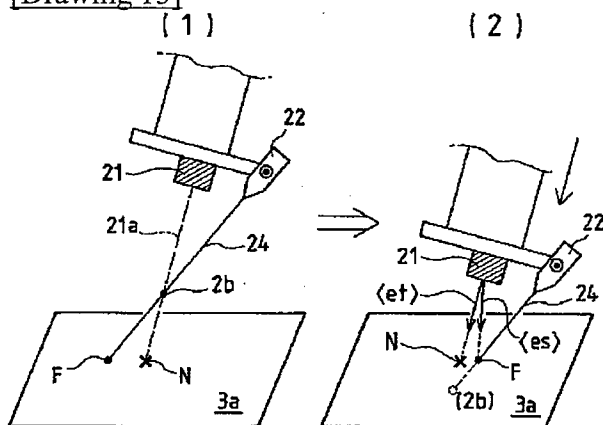
[Drawing 6]



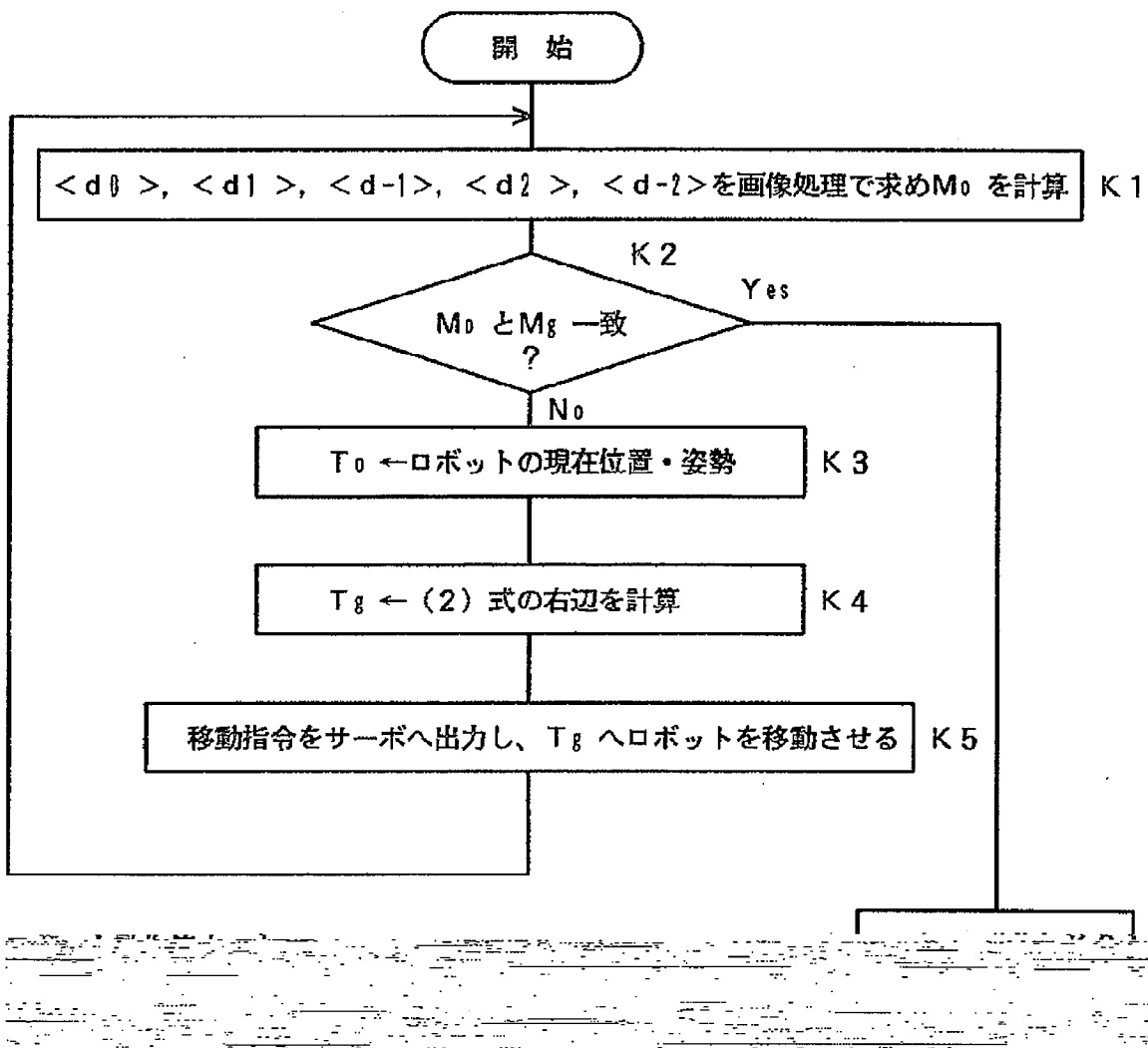
[Drawing 7]



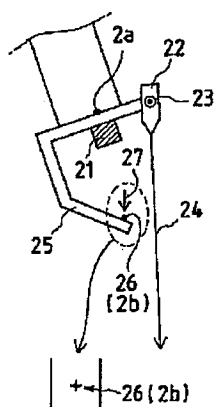
[Drawing 13]



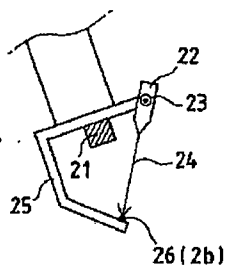
[Drawing 8]



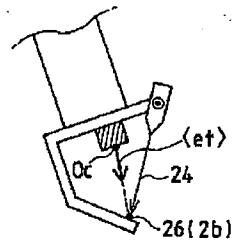
[Drawing 9]
(PR1)



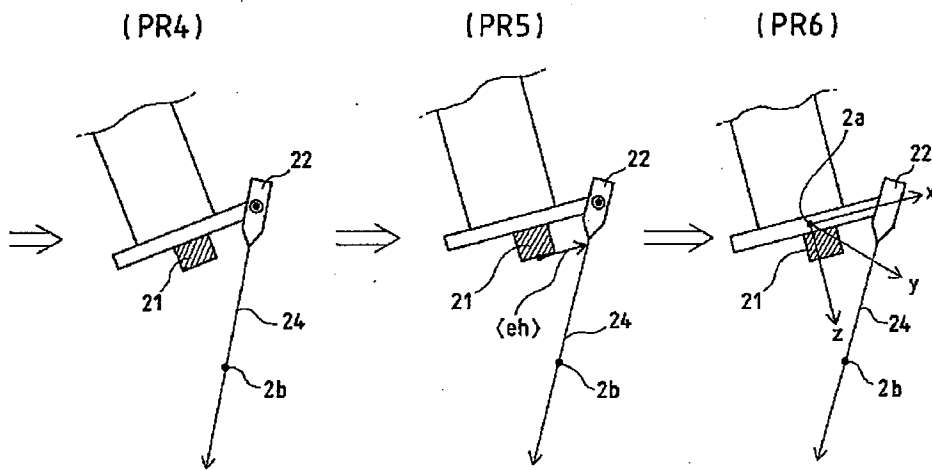
(PR2)



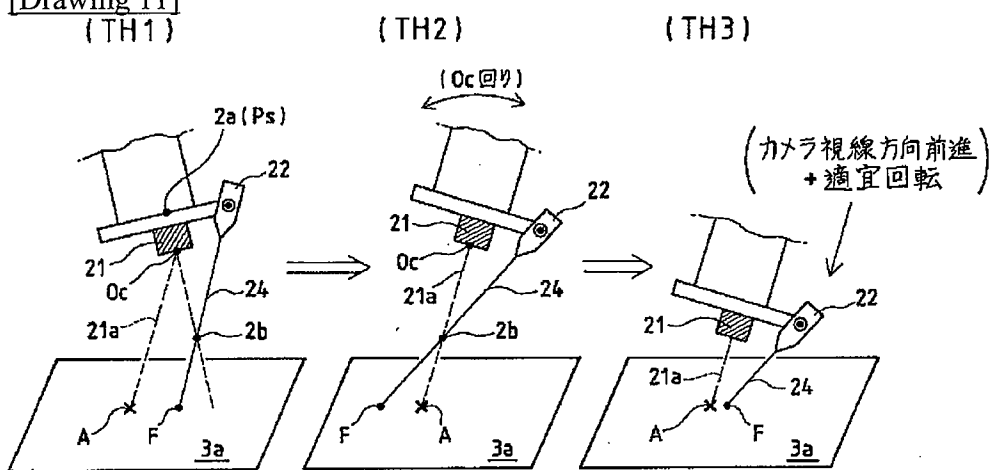
(PR3)



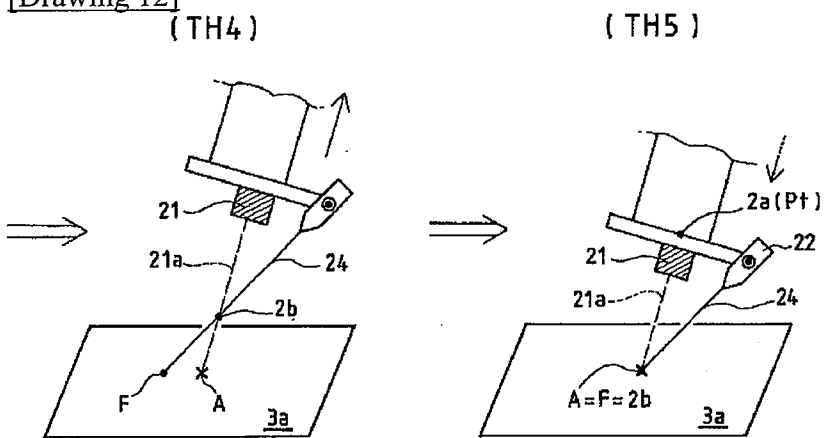
[Drawing 10]



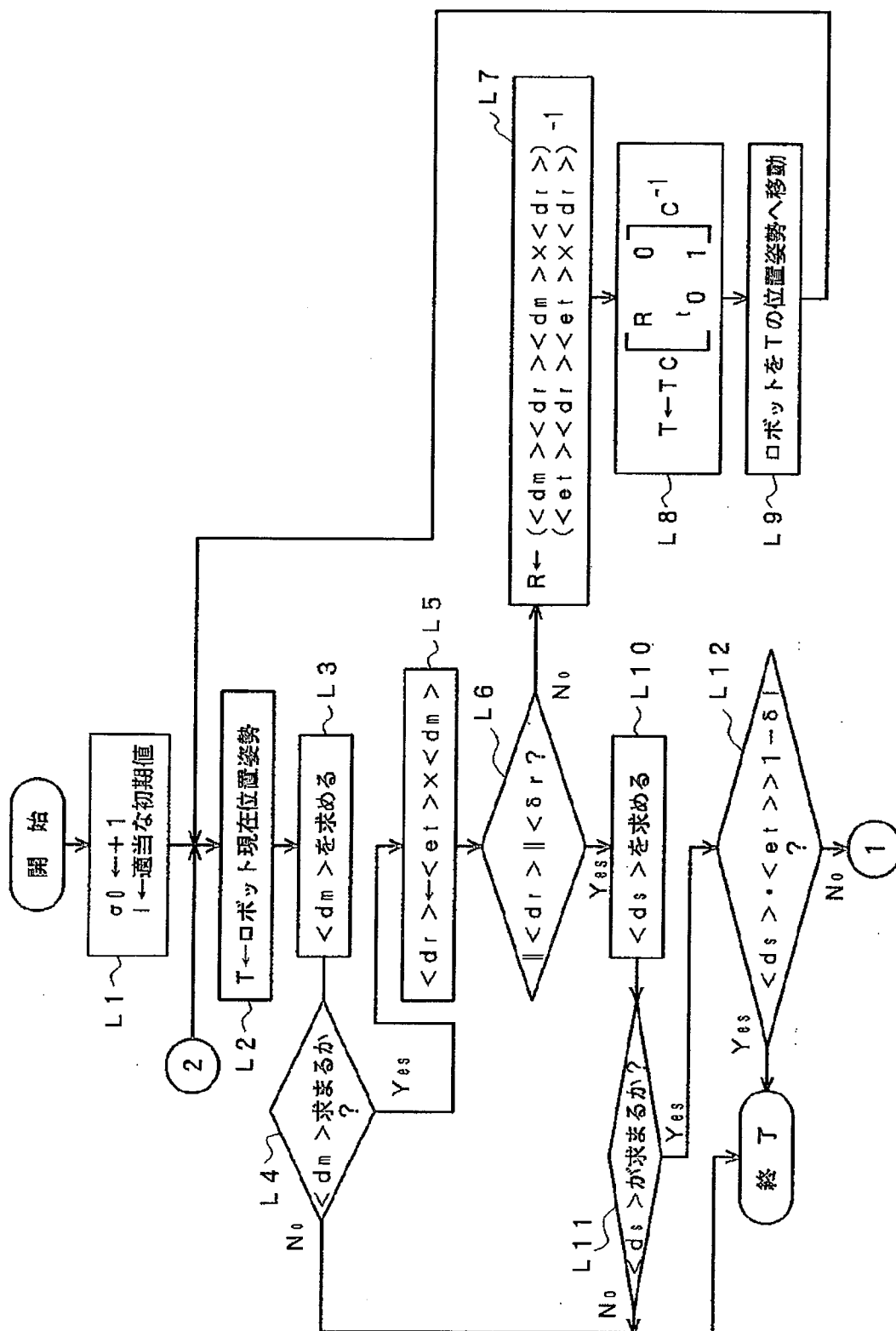
[Drawing 11]
(TH1)



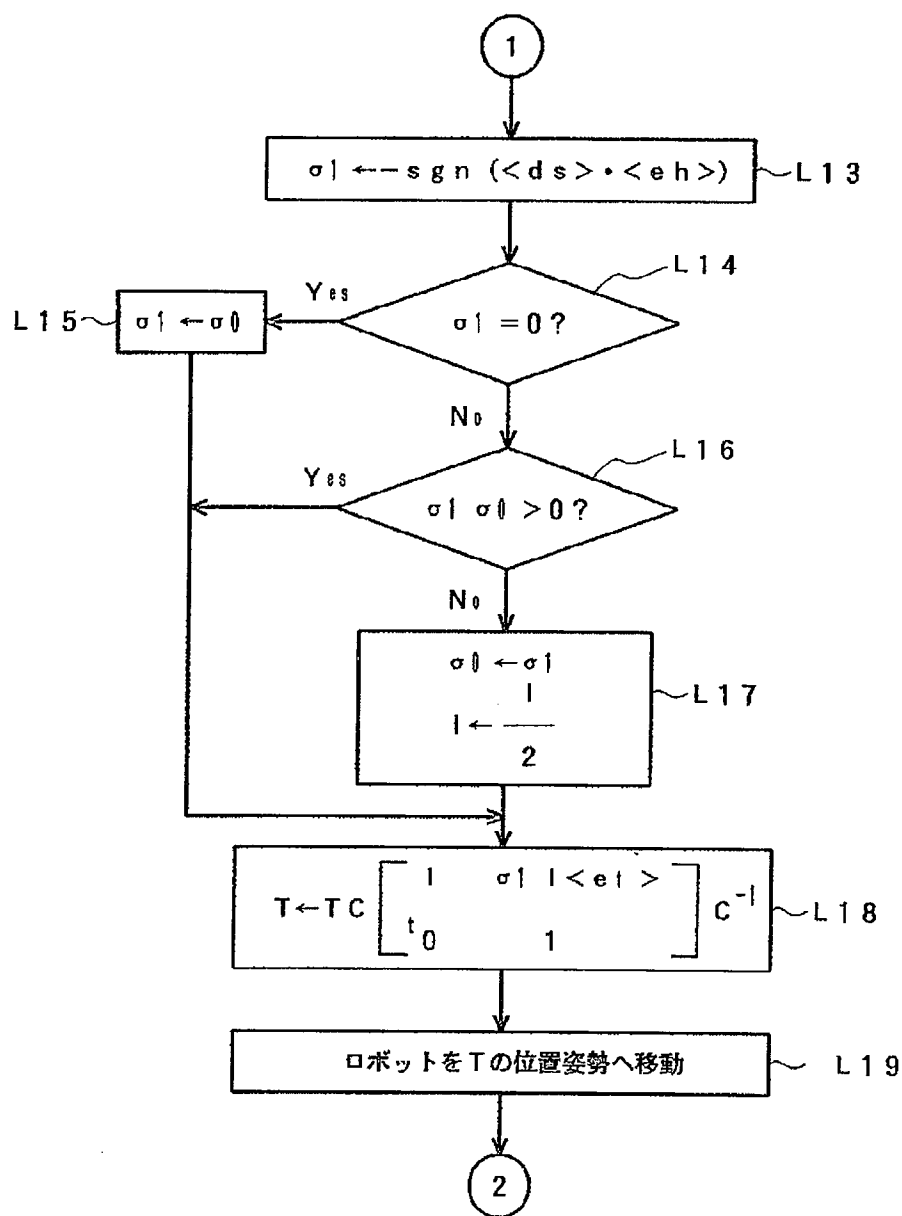
[Drawing 12]
(TH4)



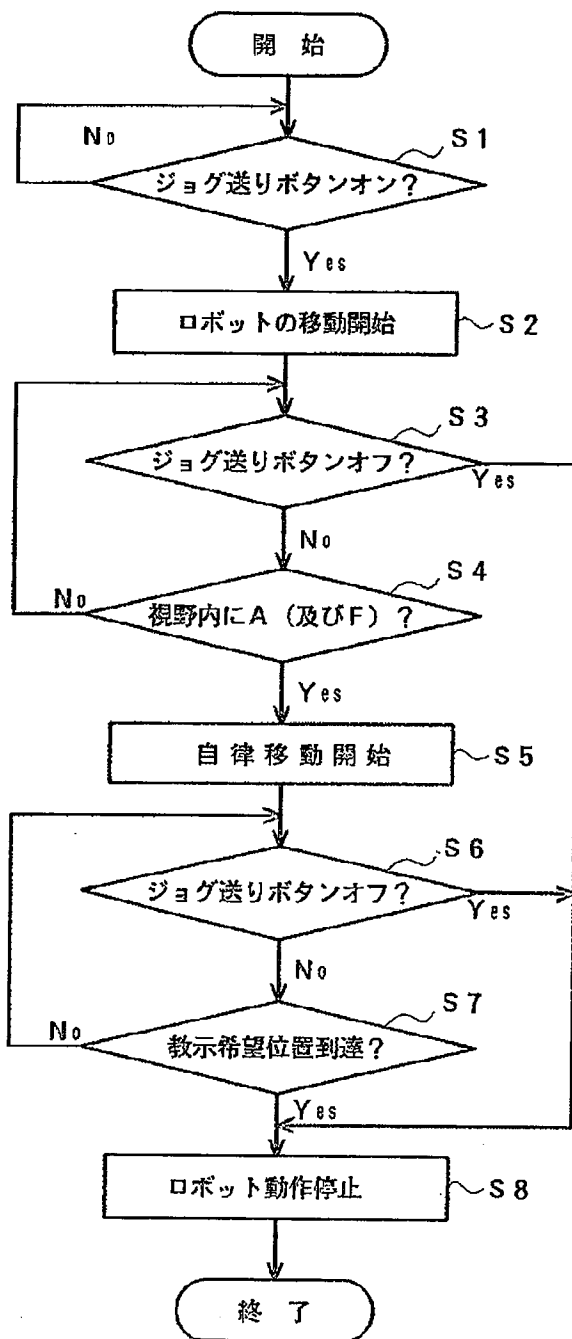
[Drawing 15]



[Drawing 16]



[Drawing 17]



[Translation done.]